Report On:

Devils Lake Outlet/Baldhill Pool Raise

Independent Analysis of Effects of the Planned Operation of the Devils Lake Outlet and Baldhill Pool Raise Projects on Groundwater Levels in the Sheyenne Delta

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1.0 Introduction

The U.S. Army Corps of Engineers (USACOE) St. Paul District contracted Barr Engineering Company to perform an evaluation and analysis of the effects on groundwater of two projects that will temporarily increase the stage of the Sheyenne River on a yearly basis. The first project is the Devils Lake Outlet, in which water from Devils Lake would be pumped to the Sheyenne River to relieve rising lake levels. The second project is the Baldhill Pool raise, in which the height of the Baldhill Pool (Lake Ashtabula) would temporarily be raised by 5 feet and discharge from the pool would increase during late spring.

At issue are the potential effects that these two projects will have on the western prairie fringed orchid (*Platanthera praeclara*), a plant classified as threatened under the Endangered Species Act of 1973. Approximately 90 percent of known western prairie fringed orchids in the United States are located in the Red River of the North valley in North Dakota and Minnesota. The orchid is found in Richland and Ransom Counties of North Dakota, approximately 1.5 to 12 miles from the Sheyenne River. The orchid grows in the sedge meadow communities (swales) that have developed on a large, glacially derived deposit of clay, gravel, and sand known as the Sheyenne Delta, which is a regional aquifer. The delta was formed on the margin of a Wisconsinan-age glacier where meltwater from the glacial Sheyenne River emptied into glacial Lake Agassiz. Approximately 15 percent of the area of the Sheyenne Delta is within the Sheyenne National Grassland, which consists of approximately 70,250 acres of public lands associated with 64,750 acres of privately-owned lands. The location of the Sheyenne National Grassland, the Sheyenne Delta, and the two projects are shown on Figure 1.

The swales where orchids are found are typically areas of ponded water. Ponding of water in the swales is believed to be caused primarily by either (1) the development of a layer of low-hydraulic conductivity silt interbedded with clay and sand in the bottom of the swale or (2) a surface expression of the water table in the Sheyenne Delta aquifer. As such, the larger-scale effects of elevated stage of the Sheyenne River would be considered potentially detrimental if such changes caused measurable increases in the elevation of the water table underneath where the orchids grow.

1.1 Planned Projects and Potential Effects

The two planned projects that are the subject of this study are the Devils Lake Outlet and the Baldhill Pool raise. Both projects are anticipated to cause temporary increases in the stage of the Sheyenne River. The projected river stage for these two projects was provided to Barr Engineering

Company by the USACOE. The scope of this study is for the groundwater effects of these two projects to be evaluated separately and independent of one another.

1.1.1 Devils Lake Outlet

The planned Devils Lake emergency outlet is designed to relieve rising lake levels in Devils Lake; a closed basin. The plan calls for water from the western portion of Devils Lake to be pumped south to the Sheyenne River. For this study, the USACOE assumes that the pumping releases a continuous volume of water at 300 cubic feet per second (cfs) and that this additional volume of water will cause increases in the river stage of the Sheyenne River between Lisbon (mile 162.0) and Kindred (mile 68.1) for the seven-month period between May 1 and December 1.

1.1.2 Baldhill Dam Raise

The planned raising of the reservoir behind Baldhill Dam (located upstream of Valley City on the Sheyenne River) for purposes of flood control is projected by the USACOE to cause river-stage changes on the Sheyenne River for a period of approximately 60 to 70 days. For the Baldhill Pool raise, the USACOE has provide projections for changes of the river stage at Lisbon (mile 162.0) and Kindred (mile 68.1) for flood frequencies of 5-year, 10-year, 20-year, 50-year and 100-year flood events. Graphs of the existing river stage and projected river-stage increases at Lisbon and Kindred are shown on Figure 2.

1.2 Study Objectives and Approach

The objective of this study is to determine the effects of increased river stages due to operation of the Devils Lake Outlet and the Baldhill Pool raise on groundwater levels and groundwater quality in the Sheyenne Delta Aquifer in the Sheyenne National Grassland of North Dakota. The results of this study are intended for use by the USACOE and others in identifying potential effects on the orchid. This report has been prepared as a stand-alone source of information on the pertinent aspects of groundwater hydrology and their application to the particular problem. Assumptions and limitations are discussed as fully as possible and the presentation is intended for those without a specialized background in hydrogeology and groundwater mechanics. A glossary of terms and a list of symbols are provided in Appendix E of this report.

The approach to evaluating the effects of the two proposed projects on groundwater levels in the Sheyenne Delta aquifer was to:

- Review in detail previous studies on the geology and hydrogeology of the Sheyenne Delta aquifer and synthesize these studies into a coherent conceptual understanding of how groundwater flows and interacts with changes in river stage, precipitation, evapotranspiration, etc. Copies of reports that describe these previous studies were provided to Barr Engineering Company by the USACOE. Additional resources were also sought out, such as bibliographies and the Internet.

- Construct a series of "profile models" of groundwater flow, roughly perpendicular to the Sheyenne River, parallel to regional groundwater flow directions, and spaced across the Sheyenne Delta aquifer. The computer code MODFLOW was used to construct these models.

- The MODFLOW profile models incorporated hydrogeologic parameters that had been measured or estimated by others in previous studies. These parameters are believed to be representative of conditions along each profile, depending upon where the profile is situated in the aquifer.

- Simulations of the conditions of the two proposed projects were performed using the MODFLOW profile models. Transient simulations were deemed to best represent the project conditions. The simulation results yielded projections of the change in the water table elevation as a function of distance from the Sheyenne River.

The profile-modeling approach was chosen over analytical analyses methods because profile modeling was able to account for changes in aquifer characteristics such as hydraulic conductivity and aquifer thickness, as well as spatial changes in topography and evapotranspiration. All of these parameters were believed to be important considerations at the start of this study. The alternative to profile modeling is a full, three-dimensional computer simulation of the aquifer. While certainly a worthwhile endeavor, three-dimensional modeling of the aquifer would be expensive and computationally demanding, whereas profile modeling is relatively quick but insightful. The advantage of the profile-modeling approach is that many more simulations (including transient simulations) could be performed with only a small loss in the "realism" of the simulation.

2.0 Site Setting

2.1 Location and Physiography

The subject area of this analysis is principally that area of the Sheyenne National Grassland in southeastern North Dakota's Red River Valley where a metapopulation of the western prairie fringed orchid (*Platanthera praeclara)* is generally found (the western prairie fringed orchid is a federally listed threatened plant species). The Sheyenne National Grassland encompasses 67,293 acres (105 square miles) and is managed by the U.S. Forest Service. It is depicted as a tallgrass prairie but a "Sandhill Prairie" is more accurate (Sieg and Wolken, 1998). The elm-basswood forest type found associated with the Sheyenne River is the most westerly extension of this forest type in the United States. Other plant species unique to North Dakota occur on the Grassland and in many circumstances, along springs that flow into the Sheyenne River.

The flat expanse of the Red River Valley is a result of the former presence of glacial Lake Agassiz, which was a shallow lake left by the retreating ice sheet during the last glaciation, some 10,000 years ago. The glacial lake drained southward through a channel now occupied by the Bois de Sioux River and a chain of lakes and marshes. The lake water then flowed east, roughly following the present course of the Minnesota River.

For the most part, the deposits at the bottom of Lake Agassiz were lacustrine (i.e. originating in a lake) clays, with some sandier beach deposits along the periphery of the lake. The lake clays were deposited on glacial till, which is also very clayey. The glacial till was deposited at the bottom and sides of the ice sheets that pre-dated the lake. A notable exception to the deposition of lake clays was in the vicinity of where the Sheyenne River entered glacial Lake Agassiz. The Sheyenne River discharged considerable amounts of sand into the lake, forming an expansive delta. When Lake Agassiz eventually drained away, a flat sand plain, resting on a flat expanse of clay, was left behind. This sandy plain is now referred to as the *Sheyenne Delta* and occupies about 750 square miles of Richland and Ransom Counties.

Recent erosion has been very slight and the only conspicuous topographic change in Richland County since the drainage of the lake has been the formation of sand dunes on the Sheyenne Delta. The Sheyenne Delta surface is covered with sand dunes over much of its extent and the topography is strongly rolling. The highest dunes border the Sheyenne River valley, where the local relief may exceed 50 feet. Most of the dunes are stabilized by vegetation but there is considerable movement of sand wherever the vegetal cover is broken. The northeastern edge of the delta is marked by a conspicuous steep slope, prominent at the Cass-Richland County boundary but it becomes less prominent southward and is barely visible south of Colfax (Baker, 1967).

The Sheyenne Delta is an extensive deposit in Richland County (550 of the 750 square miles of the Delta is in Richland County). The sand and silt of the Sheyenne Delta are as much as 200 feet thick. A notable exception to this thickness is near the Sheyenne River, where the stream has cut down into the deltaic deposits to form a broad river valley, nearly a mile wide. Within this valley, the deltaic deposits have been reworked and mixed with finer grained sediment, brought in from upstream areas.

The Sheyenne Delta is an important aquifer in Richland and Ransom Counties, due to its high sand content, which makes it very permeable. Melting snow and rain infiltrate very rapidly, resulting in almost no formation of drainage patterns, except very near the Sheyenne River valley. Groundwater generally flows toward the Sheyenne River, which is a gaining stream through most of its reach through the Sheyenne Delta (Paulson, 1964). Groundwater also is removed from the aquifer by evapotranspiration during the growing season. The Sheyenne delta aquifer contains an estimated 4 million acre-feet of ground water in storage and receives about 50,000 acre-feet of recharge during a year of average precipitation (Baker and Paulson, 1967).

2.2 Climate

Climate in Richland and Ransom Counties, where the Sheyenne Delta is located, is continental in type, characterized by short summers and long, cold winters. Summer temperatures above 90-degrees are common and winter temperatures are often as low as 20-below. The average annual precipitation is about 20 inches, three-fourths of which falls as rain in May through October (Baker, 1967; Armstrong, 1981). Somewhat more than 82 percent of the annual evaporation (about 30 inches) also occurs during the same period (Armstrong, 1981.) During the late 1980's the area experienced drought conditions with below-normal precipitation. Since 1993, above-average precipitation has been the norm.

2.3 Topography and Physiographic Setting

Richland and Ransom Counties are in the Central Lowland province of the Interior Plains. The eastern part of Richland County is in the Red River Valley physiographic division and 300 square miles in the southwestern part of Richland County and much of Ransom County are in the Drift

Prairie physiographic division. The Red River Valley can be divided into the Sheyenne Delta, which occupies approximately 750 square miles, and the Lake Agassiz plain (Baker, 1966).

Land overlying the Sheyenne Delta consists of relatively flat lake plain and gently rolling hills (Strobel and Radig, 1997). The steep banks and hills are adjacent to the Sheyenne River and were produced by surface erosion and eolian dune formation. The north end of the Sheyenne Delta stands about 100 feet above the lake plain; the delta grades outward into the plain. Outside of the dune areas, the ground is gently rolling to nearly flat. The Sheyenne River crosses the delta in a steep-sided valley that is as much as 120 feet deep and a mile wide (Baker, 1966). The area west of the Sheyenne Delta is part of a physiographic region called the "Drift Prairie", which is an area of high relief (50 to 75 feet in a square mile) and nowhere does it approach the levelness of the lake plain.

The Delta is characterized by a generally low-relief, east- to northeast-sloping surface that is covered by irregular, partly stabilized hills of windblown sand. Local relief on some of the dunes exceeds 75 feet. The dunes tend to be within one to two miles of the Sheyenne River. Shallow depressions, 1 to 10 feet deep, and sand dunes as much as 85 feet high have been formed by wind action (Baker, 1982). A series of small hills and swales on the Sheyenne Delta gives the landscape a hummocky appearance. The Sheyenne River valley is entrenched as much as 120 feet below the delta surface and exposes an incomplete cross section of the deltaic stratigraphy. The northeast edge of the delta is marked by a 75-foot high, wave-cut scarp (i.e. the delta was cut by the wave action of glacial Lake Agassiz) that becomes less pronounced southward.

The hummocky nature of the delta surface is limited mostly to the Sheyenne National Grassland and appears to be obscured to a great extent in areas of the delta that are outside of the National Grassland by recent surface disturbance; probably cultivation. The hills and swales are likely important mechanisms for recharge to the aquifer (Strobel and Radig, 1997; Shaver, 1998) and appear to control the occurrence of western prairie fringed orchid (Sieg and Wolken, 1998).

The surface of the Sheyenne Delta is noticeably devoid of developed drainage patterns. Surface drainages (other than the Sheyenne River) are poorly developed because the permeable soils that developed on the deltaic deposits cause generally rapid infiltration of snowmelt and rain through the sandy soils into the aquifer (Strobel and Radig, 1997). A number of unnamed streams enter the Sheyenne River from the Delta—most of these minor streams are only a few miles long and although spring fed, some are dry during a part of every year. Good subsurface drainage precludes the existence of permanent ponds on the delta but marshy areas are numerous in wet seasons

(Baker, 1967). In very wet years, water in some of the deeper depressions may be surface expressions of the water table.

Several man-made drainage ditches were observed on the Sheyenne Delta during the site visit on August 13, 1998. Most of these ditches ran north-south, with discharge to the Sheyenne River. Smaller laterals drained into these large ditches from croplands, though the croplands are not tiled. All of the major drainage ditches, including those running east-west on either side of major paved County roads, had standing or flowing water in them.

2.4 Land Use

Cattle grazing is the main use of public lands (Sheyenne National Grassland). On private land, land uses are crop production (corn and sunflowers, most of which are irrigated from the surficial aquifer with lesser amounts of soybeans, small grains, cattle forage, and potatoes) and cattle grazing. Corn and potatoes (that thrive in coarser-grained irrigated soils) are found most commonly on the western part of the Delta. The deltaic deposits are also most homogeneous in this area.

2.5 Geologic History

The following is a brief description of the geologic history of the area. The general processes described in this section are illustrated on Figures 3 and 4.

The deepest (and oldest) rocks underneath the Sheyenne Delta are Precambrian (i.e. greater than about 570 million years old) crystalline rocks, such as granite. These rocks were heavily eroded at the beginning of the Cretaceous Period (about 135 million years ago). The Williston Basin (the center of which is near Williston, North Dakota) began to slowly sink and fill with sediments washed in from the erosion of the Precambrian crystalline rocks. Richland County is on the edge of the Williston Basin and was probably a source area for these basin sediments (Baker, 1967).

As the Williston Basin continued to sink, the Cretaceous seas invaded the area of Richland and Ransom Counties, covering an irregular and deeply weathered ground surface with sea water. Advance of the sea to the east was slow and very shallow water covered the area. The oldest sedimentary rocks in the area (Dakota Sandstone) were deposited at this time in a near-shore, beach setting. The irregular distribution and varying thickness of the Dakota Sandstone suggests that many knobs and hills of the Precambrian granite protruded as islands in the shallow sea. The sea probably retreated briefly after deposition of the sand that now makes up the Dakota Sandstone and erosion probably removed much of the deposit from the eastern part of Richland County (Baker, 1967)

Later, water completely covered the area and black mud (Graneros Shale) was deposited in quiet, brackish water. A few thin beds and lenses of fine sand suggest that the shoreline was not far away. Younger deposits (Greenhorn Formation) contain much interbedded limestone and were probably formed in somewhat deeper water with better circulation. Younger Cretaceous rocks that are present further west (Niobrara, Pierre, and other formations) are absent under Richland County. Probably at least some of these rocks were deposited in the area but were subsequently eroded (Baker, 1967).

After the retreat of the Cretaceous seas, the area again was subjected to erosion for a very long period of time (from about 65 to 2 million years ago). Many of the Cretaceous rocks were stripped away and the weathered Precambrian rocks were exposed again in the deepest valleys. This last long period of erosion was terminated with the advance of the Pleistocene glaciers, beginning about two million years ago. It was during the Pleistocene that most of the present landscape was formed.

Richland and Ransom Counties were covered several times by sheets of glacial ice during the Pleistocene Epoch (about 2 million to 10,000 years ago) . Each ice sheet probably left deposits of drift and each succeeding ice sheet probably removed and redistributed part of the deposits of its predecessor. The deposits of the various ice sheets are so similar in lithology that there is no ready means of distinguishing between them. Great thicknesses of glacial drift were deposited and by the time of the last glacial retreat the original topography was completely buried. A portion of the last ice sheet broke off and melted in place and the stagnant ice left characteristic topographic features in the southwestern corner of Richland County. The stagnant ice deposits were overridden by a minor re-advance of the glacier and then the final withdrawal of the ice began (Baker, 1967).

The regional slope in eastern North Dakota was to the northeast and as the last ice sheet retreated to the north it blocked the drainage. A large proglacial (i.e. in front of the glacier) lake (Lake Agassiz) was formed in eastern North Dakota and western Minnesota. Most of Richland and Ransom Counties are within the Lake Agassiz basin. At its maximum, Lake Agassiz extended from northeastern South Dakota to northern Manitoba (more than 550 miles) and had an average width of 150 miles. The greatest depth of Lake Agassiz in Richland County (difference between lowest point on the lake plain and the highest beach) was about 150 feet (Baker, 1967). The ancestral Sheyenne River flowed into Lake Agassiz a few miles east of what is now the town of Lisbon.

Lake Agassiz had an outlet to the south through a channel now occupied by the Bois de Sioux River and a chain of lakes and marshes. The outlet continued westward through the River Warren, which generally followed the course now occupied by the Minnesota River. Water flowing out of the lake eroded the bottom of the channel and this deepening of the outlet caused a general lowering of the water level in the lake. The materials in the floor of the channel were not homogeneous; consequently the rate of erosion was not uniform. During periods of rapid erosion, the lake level fell rapidly; during periods of slow erosion, the lake level changed slowly and well-defined shorelines were formed. As the ice continued to retreat, lower outlets were uncovered to the northeast and Lake Agassiz gradually receded from Richland and Ransom Counties. Possibly a re-advance of the glacial ice blocked the northern outlets and caused the lake to be refilled to the level of the southern outlet. The effect of the draining and refilling was slight; a few scattered deposits of silt on the lake plain may have been left behind during the second stage of the lake (Baker, 1967).

Many of the surficial features of Richland and Ransom Counties were formed in Lake Agassiz. During the highest stage of the lake, a well-defined shoreline (referred to as the “Herman shoreline”) was created and an extensive delta was formed at the mouth of the Sheyenne River. This delta prograded (i.e., grew) from west to east, depositing sand and silt as it built out into the lake, much like modern deltas, such as the Nile Delta, do today. Baker (1967) has several block diagrams that illustrate how the delta deposits likely formed. As the ice sheet dwindled and the lake was drained, other beaches were formed at lower levels and parts of the courses of four of these lower beaches can be traced through Richland County. During the life of Lake Agassiz, wave action smoothed the lake floor and a blanket of clay and silt was deposited in the deeper parts of the basin (Baker, 1967).

When the glacial ice far to the north finally melted and Lake Agassiz was drained, the lake plain had essentially the form that is seen today. Recent erosion has been very slight and the only conspicuous topographic change since the drainage of the lake has been the formation of sand dunes on the Sheyenne Delta and in the vicinity of Hankinson. These dunes probably were formed very soon after the drainage of the lake and have changed little in recent times. The Sheyenne River has cut through the deltaic deposits, forming a broad meander-belt valley in which the deltaic sands have been reworked and mixed with silts and clays brought into the area from upstream. Oxbow lakes have formed where meanders have been abandoned. At least one terrace level is present in the river valley (a terrace represents an earlier elevation of the river).

2.6 Stratigraphy

Stratigraphy refers to the sequence of rock deposits, with the deepest rocks generally being the oldest and younger rocks deposited on top. The oldest rocks (Precambrian granites) are igneous and metamorphic, whereas all younger rocks in the area are sedimentary in origin. A sedimentary rock is simply a lime mud, clay, silt, sand, or gravel that has been cemented into a stone through a process called "diagenesis" that is substantially influenced by time and pressure during burial. The Pleistocene glacial deposits are generally not yet formed into rock and are referred to as "unconsolidated." Baker (1967) provides a stratigraphic column for Ransom and Richland Counties that summarizes the general stratigraphy of the area:

Age	**Unit**	**Description**	**Thickness (feet)**
Quaternary (recent)	Alluvium	Silt and clay on flood plains of modern streams	0-40
Quaternary (Pleistocene)	Glacial Drift	Glacial till, glaciofluvial deposits, and glacial lake sediments	154-490
Cretaceous	Greenhorn Fm.	Black limey shale, generally contains minute white "specks" of calcium carbonate; interbedded with white to buff limestone	0-212
Cretaceous	Graneros Shale	Black shale, locally with streaks and lenses of white sand; often marine fossils	0-160
Cretaceous	Dakota Sandstone	White quartz sand with interbedded varicolored sandy shale, siltstone, and clayey sandstone	0-238+
Cretaceous (?)	Undifferentiated rocks	Light gray to moderate yellowish-green "nodular" sand, interbedded with varicolored clay	0-61
Precambrian	Undifferentiated crystalline rocks	"Granite." Generally deeply weathered in upper part	?

2.7 Geology of the Sheyenne Delta and Associated Deposits

The Sheyenne Delta: covers about 750 square miles, of which 550 is in Richland County. The extent of the Delta is shown on Figure 5. The Delta is crossed by the Sheyenne River, which is deeply entrenched into the delta. The northeastern edge of the delta is marked by a conspicuous steep slope, prominent at the Cass-Richland County boundary but it becomes less prominent southward and is barely visible south of Colfax. Near Wyndmere, there is no surface expression of the delta edge and the limits of the delta must be mapped on the basis of the changes in lithology (Baker, 1967).

The surface of the Sheyenne Delta is covered with sand dunes over much of its extent (though they are most prevalent near the Sheyenne River) and the topography is strongly rolling in the dune areas. The highest dunes border the Sheyenne River valley, were the local relief may exceed 50 to 75 feet. Most of the dunes are stabilized by vegetation but there is considerable movement of sand wherever the vegetal cover is broken (Baker, 1967).

The deltaic deposits generally become finer from west to east across the Sheyenne Delta, which probably is the result of finer sediment being carried farther into Lake Agassiz before settling out and being deposited. Grain size in the deltaic deposits generally increases in both the upward and shoreward (southwest) directions because of the progradation of the delta into glacial Lake Agassiz (Cowdery and Goff, 1994). Along the western extent of the Sheyenne Delta in Ransom County, the deposits are generally medium to coarse sand. Near the Richland-Ransom County boundary, the delta sediments are primarily fine to medium sand but the average grain size decreases eastward. Near the eastern edge, the predominant lithology is very fine sand and silt with some interbedded clay (Baker, 1967).

Stratification is well exposed in only one known locality, near the eastern edge of the delta (west edge of Sec. 14, T 136 N, R 51 W), where fine sand, silt, and clay are interbedded and the sand and silt are cross stratified (Baker, 1967). The most common type of stratification is ripple lamination. Some silt and very fine sand beds are strongly contorted on a small scale. The mode of formation of these contortions is not known but such contortions, as well as the ripple laminations, are common features of deltaic and flood-plain deposits (Baker, 1967).

As the delta advanced into Lake Agassiz, it built out over its own bottomset beds and over existing lake-floor deposits. Because of this, it is impossible to distinguish in test holes between delta bottomsets and lake-floor deposits of essentially the same composition; therefore a boundary cannot be established between delta and lake-floor deposits (Baker, 1967). Pleistocene lacustrine clays about 100 feet thick underlie the Sheyenne Delta aquifer throughout the study area (Downey and Paulson, 1974). The clays, which are plastic and have low hydraulic conductivity, form a relatively impermeable basal unit to the aquifer. A thick sequence of Pleistocene-age till and stratified drift underlies the lacustrine clays (Downey and Paulson, 1974).

Pleistocene glacial drift (sediment deposited by glaciers) mantles the entire area underneath the delta and along its margins; the known thickness of the drift, including the deposits of glacial Lake Agassiz, range from 154 to 490 feet (Baker, 1966). Glacial drift, representing several ice sheets, may be present but cannot be differentiated except in a few places. All of the surficial features can be attributed to the last ice sheet (Mankota advance); local zones of oxidized till, extensive bodies of buried outwash, and buried lake silts are the only indications of the presence of older drift in the subsurface (Baker, 1966).

The delta deposits can be divided into three units (Baker, 1967): (1) a lower unit of silt interbedded with clay and sand, which is thickest near the eastern margin of the delta and thins westward; (2) an upper unit of well-sorted sand, which is thickest in the west and thins eastward; and (3) a thin layer of wind-blown sand, which covers the entire delta. The lower silty unit is more than 150 feet thick at the eastern edge of the Delta, less than 50 feet thick near the Richland-Ransom County boundary, and is entirely absent near the western edge of the Delta in Ransom County. The sand unit is as much as 100 feet thick near the Richland-Ransom County boundary, and is entirely absent near the eastern edge of the Delta in Ransom County. Its average thickness in Richland County is about 60 feet. The grain size of the sand generally decreases eastward from medium and coarse along the Richland Ransom County boundary to very fine in the eastern part of the Delta near Walcott. The thickness of the wind-blown surficial sand is generally less than 10 feet but may be as much as 50 feet in the highest dunes.

The greatest thickness of sand penetrated during test drilling on the Sheyenne Delta was 107 feet in test hole 2185 (135-52-21ccc) but it is questionable whether this figure should be taken as the thickness of the delta deposits at this point - the drill passed from sand into silty clay and the hole was stopped after drilling only a few feet into the clay before reaching the underlying till. The greatest known thickness of sand, silt, and clay; that is, the greatest known depth to glacial till is 198 feet penetrated in test hole K-2R (136-51-7ddd). The average depth to till is 150 feet. The delta sand is only 45 feet thick near the southern edge of the Delta and has no clay or silt under it (Baker, 1967).

3.0 Previous Studies

An annotated bibliography of previous studies that were provided to Barr Engineering Company is presented in Appendix A. These previous studies are believed to encompass most, if not all data and information that now exists on the hydrogeology of the Sheyenne Delta aquifer that is pertinent to this study. These previous studies are summarized below.

Paulson, Q.F., 1964. Geologic factors affecting discharge of the Sheyenne River in southeastern North Dakota: USGS Professional Paper 501-D, p. D177-181.

- Throughout much of its length the Sheyenne River is fed almost wholly by overland runoff from glacial till. However, in the reach 75 to 145 miles upstream from its junction with the Red River of the north, the Sheyenne drains groundwater from sand deposits in the Sheyenne Delta, into which its valley is deeply incised. Discharge measurements made in the fall of 1963 indicated an average gain of 28.8 cfs in this reach.

Baker, C.H., Jr., 1966. Geology and ground-water resources of Richland County, North Dakota, Part II, Basic data: North Dakota Geol. Survey Bull. 46 and North Dakota State Water Comm. County Ground Water Studies 7, 170 p.

- This is a compendium of water-quality data, well construction information, and well logs for Richland County. Includes map of well locations. Cited in other reports.

Baker, C.H., Jr., 1967. Geology and ground water resources of Richland County, Part 1, Geology: North Dakota Geological Survey Bulletin 46 and North Dakota State Water Commission County Ground Water Studies 7, 45 p.

- Richland County comprises an area of approximately 1,450 square miles in the southeastern corner of North Dakota. About one-fifth of the county is in the Drift Prairie physiographic division; the remainder is in the Red River Valley (basin of glacial Lake Agassiz) physiographic division. The stratigraphy of the sedimentary rocks underlying the Pleistocene deposits is relatively uncomplicated. Cretaceous Dakota Sandstone lies unconformably on the Precambrian crystalline basement. The Graneros Shale and the Greenhorn Formation, both of Late Cretaceous age, overlie the Dakota in most of the county, and no indurated rocks younger than the Greenhorn are present.

- Pleistocene glacial drift mantles the entire county; the known thickness of the drift, including the deposits of glacial Lake Agassiz, range from 154 to 490 feet. Drift representing several ice sheets may be present but cannot be differentiated except in a few places. All of the surficial features of the county can be attributed to the last ice sheet (Mankota advance); local zones of oxidized till, extensive bodies of buried outwash, and buried lake silts are the only indications of the presence of older drift in the subsurface.

- The major surficial features of the Drift Prairie in the county are stagnation moraine, a large body of overridden pitted outwash, and an ice-marginal drainage channel. Minor features include end moraine, ground moraine, and kames.

- The flat expanse of the Red River Valley is interrupted by the Sheyenne Delta and by the major shorelines of glacial Lake Agassiz. The Sheyenne Delta is an extensive deposit in Richland County and an important aquifer. It covers 550 square miles and consists of sand and silt as much as 200 feet thick. The lake-floor deposits, where present, may include two distinct lithologies, but the upper unit is thin and irregularly distributed. Few Pleistocene fossils have been found in Richland County, and most of the available material is of little value for age determinations

Baker, C.H. Jr. and Q.F. Paulson, 1967. Geology and ground water resources of Richland County, North Dakota, Part III - Ground water resources: North Dakota Geological Survey Bulletin 46 and North Dakota State Water Commission County Ground Water Studies 7, 45 p.

- Water supplies in Richland County are obtained mainly from ground water. The most important sources are the shoreline deposits of glacial Lake Agassiz. These deposits contain two main aquifers— identified as the Sheyenne delta aquifer and the Hankinson aquifer, which have a combined area of about 400 square miles. They consist of well-sorted deposits of sand that are at least 50 feet thick in most places and as much as 100 feet thick near the western boundary of the county. Grain-size analyses indicate possible well yields of at least 50 gallons per minute in most places and as much as 1,000 gallons per minute in a few places. The aquifers are relatively undeveloped and water levels are only a few feet below land surface. The Sheyenne Delta aquifer contains an estimated 4 million acre-feet of groundwater in storage and receives about 50,000 acre-feet of recharge during a year of average precipitation. The water in the Sheyenne Delta and Hankinson aquifers generally contains less than 500 parts per million dissolved solids, and, although hard, is usable for most purposes.

- Aquifers of less importance are associated with the till deposits and in the bedrock formations, chiefly the Dakota Sandstone. The aquifers in or associated with the till generally are smaller and less productive. Aquifers in the bedrock yield water that is of rather poor chemical quality. However, wells developed in these sources may be capable of yielding 500 gallons per minute in places.

Downey, J.S. and Q.F. Paulson, 1974. Predictive modeling of effects of the planned Kindred Lake on ground-water levels and discharge, southeastern North Dakota: USGS Water-Resources Investigations 30-74, 22 p.

! A digital model was used to describe a groundwater system in glacial deltaic deposits near Kindred, North Dakota, and to predict the effects of a planned lake on groundwater levels and groundwater discharge. A digital computer was used to solve the finite-difference equations for groundwater flow. The model analysis delineated an area of about 140 square miles that would be affected by rising water levels as a result of the lake. The rise of water levels depends on time and hydraulic properties of the aquifer. The maximum projected rise in water levels should occur in about 50 years. Evapotranspiration from the water table is presently near maximum and therefore the projected water-level rise will not be controlled by evapotranspiration. Existing artificial drains will be effective in limiting the extent of water-level rise.

Armstrong, C.A., 1979. Ground-water basic data for Ransom and Sargent Counties, North Dakota: North Dakota Geological Survey Bulletin 69 - Part II and North Dakota State Water Commission County Ground-Water Studies 31 - Part II, 637 p.

! This is a compendium of water-quality data, well construction information, and well logs for Ransom and Sargent Counties. Includes map of well locations. Cited in other reports.

Bluemle, J.P., 1979. Geology of Ransom and Sargent Counties, North Dakota: North Dakota Geological Survey Bulletin 69 - Part I and North Dakota State Water Commission County Ground-Water Studies 31 - Part I, 84 p.

! Ransom and Sargent Counties, located at the eastern edge of the Williston Basin are underlain by 500 to 1,800 feet of Paleozoic and Mesozoic rocks that dip gently to the northwest. The Cretaceous Belle Fourche, Greenhorn, Carlile, Niobrara, and Pierre Formations lie directly beneath the glacial drift, and the Sheyenne River, especially in northwestern Ransom County. The Pleistocene Coleharbor Group, which covers most of the area, consists mainly of glacial, fluvial and lake sediment. The Coleharbor Group averages about 200 feet thick but it is as much as 400 feet thick near Gwinner. The Holocene Oahe Formation occurs in parts of the area, chiefly sloughs, river bottomland, and dune fields. It consists mainly of alluvial and eolian sediment.

! Most of the two-county area is part of the Glaciated Plains, an area characterized by nearly level to undulating topography. Rolling to steep land is found along the Sheyenne River valley, on the Prairie Coteau in southeastern Sargent County, in areas of sand dunes in the eastern part of Ransom County, and western Sargent County, and in areas of intense ice thrusting, which are prominent in western Sargent County.

! Several distinct till layers that have been identified in Ransom and Sargent Counties attest to repeated glacial advances, both prior to and during Wisconsinan time. Following the earliest flooding of western Sargent County by glacial Lake Dakota, a re-advance of the glacier resulted in large-scale thrusting. The early glacial Lake Agassiz flooded eastern parts of the two counties, resulting in discontinuous lake and shore sediments above the Herman level. Later, the Sheyenne Rive built a large delta into the lake while it stood at the Herman level. After Lake Agassiz drained, wind erosion built large dunes on the Sheyenne Delta.

Armstrong, C.A., 1981. Supplement to: Predictive modeling of effects of the planned Kindred Lake on ground-water levels and discharge, southeastern North Dakota: USGS Open-File Report 81-646, 15 p.

! A digital model was used to describe a ground-water system in glacial deltaic deposits near Kindred, North Dakota, and to predict the effects on ground-water levels of a planned lake at 950-, 960-, 970-, 984-, and 995-foot stages. This model is a supplement to an earlier model of the ground-water system for a planned lake at the 984-foot level (Downey and Paulson, 1974). The model analysis indicates that only the area within about 2 miles of the present Sheyenne River would be affected by rising water levels as a result of a lake stage at 995 feet. The rise of water levels depends on time and hydraulic properties of the aquifer. The maximum projected rise in water levels is expected to occur in about 50 to 100 years. Evapotranspiration and existing drains will be effective in limiting the extent of water-level rise. Consequently, the area affected by rising water levels at each lake stage will be much smaller than that shown by the earlier model at the 984-foot stage.

Armstrong, C.A., 1982. Ground-water resources of Ransom and Sargent Counties, North Dakota: North Dakota Geological Survey Bulletin 69 - Part III and North Dakota State Water Commission County Ground-Water Studies 31 - Part III, 51 p.

- Groundwater in Ransom and Sargent Counties is available from glacial-drift aquifers of Quaternary age and from the Dakota aquifer system of Cretaceous age. Glacial-drift aquifers with the greatest potential for development are the Spiritwood aquifer system and the Brampton, Elliott, Gwinner, Elglevale, Milnor Channel, Oakes, Sheyenne Delta, and Sand Prairie aquifers. Properly constructed wells in the more permeable parts of these aquifers will yield from 500 to 1,5000 gallons per minute. A total of about 3,000,000 acre-feet of water is available from storage in the glacial-drift aquifers. Water from the glacial-drift aquifers varies in chemical quality. Dissolved solids concentrations in samples from these aquifers range from 203 to 4,670 milligrams per liter.

- The top of the Dakota aquifer system underlies Ransom and Sargent counties at depths that range from 500 to 1,000 feet below land surface. Water in the Dakota is under sufficient head to flow at land surface in most parts of the two-county area. Unrestricted flows from wells tapping the aquifer system generally are less than 10 gallons per minute but may be as much as 50 gallons per minute. Water in the Dakota aquifer system generally is a sodium sulfate type and has dissolved-solids concentrations ranging from 2,170 to 3,340 milligrams per liter.

Cowdery, T.K. and K. Goff, 1994. Nitrogen concentrations near the water table of the Sheyenne Delta aquifer beneath cropland areas, Ransom and Richland Counties, North Dakota: Proceedings of the North Dakota Water Quality Symposium, Fargo, North Dakota, March 30-31, 1994, North Dakota State University Extension Service, p. 89-102.

- Purpose: land-use study to examine the human activities and natural factors affecting the quality of shallow (within 3 meters of land surface) groundwater underlying agricultural areas on the glacial, near-shore deltaic-facies deposits of the Sheyenne Delta. The Sheyenne Delta was selected for this study because it is a surficial aquifer and is susceptible to contamination from the land surface.

- Homogeneous land use patterns and local groundwater discharge to the Sheyenne River simplify groundwater constituent sources and make the Sheyenne Delta an excellent land-use study site. Cattle grazing is the main use of public lands (Sheyenne National Grassland). On private land, land uses are crop production (corn and sunflowers, most of which are irrigated from the surficial aquifer with lesser amounts of soybeans, small grains, cattle forage, and potatoes) and cattle grazing.

- The paper is a review of both the 1993 nitrate-nitrogen data collected by NAWQA study and historical nitrate-nitrogen data. Purpose of study is to (1) describe nitrate concentrations near the water table beneath cropland areas after the early part of the 1993 growing season (2) relate nitrate concentration to spacial changes in land use and geology; groundwater recharge and depth to water table; and precipitation and (3) to suggest explanations for these relations.

- Samples were collected from 29 randomly selected wells during July and August 1993. Seven existing and 22 newly constructed wells form the network sampled for this study. The seven existing wells were installed by the NDSWC or the USGS during 1963 or 1972. Rainfall on the Delta during the 1993 growing season was 166 percent of average for the last 31 years.

- Historical nitrate concentrations come from 70 samples by the NDSWC and 3 by USGS. These data were grouped into (1) High Nitrate (> 0.68 mg/L); (2) Medium Nitrate (0.23-0.68 mg/L) and (3) Low Nitrate (<0.23 mg/L). Samples with high to medium concentrations cluster on the west (beach) side of the delta, south and east of the Sheyenne River and west of the Sheyenne National Grassland.

- Progradation of the delta into a water body resulted in a general trend of increasing grain size in both the upward and beachward directions. Therefore the Delta aquifer should generally be hydraulically less conductive toward the east-northeast - this trend is documented by Downey and Paulson (1974) who also noted that the entire delta thins to the west as the Lake Agassiz basin approaches the surface.

- Shallow, high-production irrigation wells and crops such as corn and potatoes (that thrive in coarser-grained irrigated soils) are found most commonly on the western part of the delta. The deltaic deposits are also most homogeneous in this area.

- Because nitrogen application rates are greatest on potatoes and corn corps, it is reasonable to expect that the shallow ground water in the western part of the delta has the highest concentrations of nitrate in the study area. Nitrates may also be concentrated by pumping high-nitrate groundwater for irrigation.

- As water table rises, the time required for infiltrating water to reach the water table (lag time) decreases. This lag time increases in December when water table depth increases. Microbial denitrification in groundwater is not a likely mechanism for lower nitrate concentrations in wet years. DOC concentrations are too low.

Hopkins, D.G., 1996, Hydrologic and abiotic constraints of soil genesis and natural vegetation patterns in the sandhills of North Dakota: Ph.D. thesis, North Dakota State University.

- The Sheyenne Delta aquifer is a calcium-bicarbonate type water characterized by low salinity and sodium content. Water from the Dakota aquifer enters the Sheyenne Delta aquifer only as flowing wells. The water is seven times more saline and nearly 40 times higher in sodium than water in the Sheyenne Delta aquifer. The Dakota aquifer is classified as a sodium-sulfate type but chloride is the dominant anion in 10 of 74 wells tested.

- Two new land use practices are occurring in the sandhills: one is management response to a natural, though undesired, example of plant succession, (leafy spurge has infested approximately 19% of the Sheyenne National Grasslands and significantly reduced rangeland productivity and stocking rates) the other a result of economic opportunities in agriculture.

- Both the USFS and private landholders in the sandhills are applying 2,4-D and picloram (Tordon) to control leafy spurge. The threat these herbicides pose to groundwater quality has not been assessed in the Sandhills. In the past, local irrigation has been dedicated to corn for grain or silage, but irrigated potato production has increased rapidly in the Sandhills during the last few years. Corn acreage is being converted to potato production and several large storage facilities have been erected. Ransom County acreage planted in irrigated potatoes was virtually nil in the mid-1980s and was about 1134 hectares in 1994. The number of application permits to withdraw water from the Sheyenne delta aquifer for irrigation has increased markedly.

Strobel, M.L. and S.A. Radig, 1997. Effects of the 1993 flood on water levels and water quality in the Sheyenne Delta aquifer, southeastern North Dakota, 1993-94. USGS Water-Resources Inv. Report 97-4163, 43 p.

- This study was conducted to evaluate the effects of precipitation and flooding on water levels in the Sheyenne Delta aquifer and to evaluate the variations in water quality that are related to the precipitation and flooding. Water-level, streamflow, and water-quality data collected prior to July 1993 were assumed in this study to be representative of pre-flood conditions. Data collected from July 1993 through May 1994 were used to evaluate the groundwater response. The study found that the largest water level rises in the aquifer are associated with low-relief areas, where rapid infiltration of snowmelt, runoff, and precipitation can take place. Snowmelt and precipitation in high-relief areas, typically in areas near the river, either travel as surface runoff to low-relief areas or to the river or infiltrate to the water table and flow in the direction of the steep hydraulic gradient toward the river.

- The water table elevations were found to change little during frozen winter months. Delayed recharge may be taking place in areas with thicker unsaturated deposits, due to delayed recharge percolation to the water table. During March, water levels in the aquifer rose by more than 2 feet in some areas as substantial recharge took place over large parts of the aquifer, in response to precipitation and snow melt. Water levels then generally declined during the first half of April as snow melt declined. Reversals of groundwater flow very near the river were inferred from water-level data during high stage conditions in the river (i.e. bank storage). These reversals were "temporary" (less than one month) in duration and very localized near the river (less than one mile from river). Overall hydraulic gradients to the river decreased slightly during this period, due both to higher river stage and to increased infiltration over the aquifer. The authors estimate that high stage levels on the Sheyenne River in July and August 1993 probably caused water-table gradients near the river to reverse and water from the river flowed into the aquifer as temporary bank storage. "Direct effects of the 1993 flood on water levels in the aquifer probably were limited to the area adjacent to the river." "However, excessive precipitation associated with the flood probably affected water levels throughout the aquifer. Water levels in two observation wells in the aquifer indicate that the water table generally was about 2 feet higher during the fall and winter of 1994 than during the fall and winter of 1993." (P. 35).

- The aquifer is generally a calcium bicarbonate or calcium magnesium bicarbonate type, with dissolved-solids concentrations ranging from 269 to 1,820 mg/L. "No discernable differences existed between the pre-flood data and the post flood data for both dissolved-solids and chloride concentrations." (P. 35) The only pesticide detected was picloram and it was randomly distributed (reflecting local land use).

Shaver, R., June 9, 1998. North Dakota State Water Commission Office Memo to David Spryncznatyk, State Engineer, through Milton O. Lindvig, Director, Water Appropriations Division - Conditional Water Permit Application #5188, 31 p.

- On November 24, 1997, Ransom-Sargent Water Users, Inc. (Don Smith) submitted a conditional water permit application to the State Engineer to divert 550 acre-feet of groundwater annually from points of diversion located in the W1/2 of S. 11, T 134N, R 54W at a maximum pumping rate of 1,300 gpm. The diversion is for municipal-rural-domestic use. At a hearing on February 10, 1998, a letter from Allyn J. Sapa of the U.S. Fish and Wildlife Service was submitted that expressed concern over potential adverse impacts on the western fringed orchid (*Platanthera praeclara*) as a result of the proposed appropriation. A letter from Steve Williams of the US Forest Service was also submitted that expressed concern over potential impacts on the orchid and plant productivity in the nearby Sheyenne National Grasslands. A letter from Richard D. Nelson of the US Bureau of Reclamation requested that the State Engineer perform an analysis to delineate the maximum area of drawdown influence from the proposed pumping and the effects on groundwater seeps.

- To a great extent, the recharge to the Sheyenne Delta aquifer can be characterized as depression focussed (Lissey, 1968). During the winter, a frost zone develops at or near the water table. Snow accumulates in depressions and on adjacent topographic-high areas. In the spring, snow melts before the frost zone dissipates. Snowmelt originating in the upland areas accumulates in depressions from surface runoff because of the inability to infiltrate through the frost zone. Ponded water in depressions infiltrates downward to the saturated zone after the frost zone dissipates.

- Recharge to the Sheyenne Delta aquifer takes place primarily during the spring. During most summer months, recharge to the aquifer is minor because potential evapotranspiration exceeds precipitation. Summer precipitation events generally are not large enough to overcome soil-moisture deficits and generate recharge. Occasionally, during the fall precipitation exceeds both evapotranspiration and soil-moisture deficits and recharge takes place. Even when recharge does not occur during the fall, soil-moisture deficits generally are reduced, significantly affecting the magnitude of the following spring recharge event.

- Depth to the water table is generally less than 8 feet. The capillary fringe of water table and root zone are coupled. As a result, natural discharge from the Sheyenne Delta aquifer is due, in large part, to evapotranspiration. Armstrong (1982) suggests in a year with normal precipitation, between 14 and 50 percent of precipitation that infiltrates to the aquifer as recharge eventually discharges to the Sheyenne River. Thus, about 40 to 86 percent of natural discharge from the Sheyenne Delta aquifer is due to evapotranspiration.

- In the central part of the grassland (away from the Sheyenne River) the hydrogeologic setting is conducive to the development of numerous local flow systems (cells) in which underflow may be insignificant. Within each local flow system, recharge is from relatively direct infiltration of precipitation and local runoff (snow melt) that occurs primarily during the spring. The capillary fringe of the water table and root zone are coupled and therefore discharge primarily is from evapotranspiration that takes place during the growing season. "Thus, movement of ground water is largely vertical, and flow paths are relatively short."

- William M. Schuh, Hydrologist Manger, NDSWC summarized storativity calculations for Hecla, Hamar, and Ulen soils (5 sites) in the Oakes aquifer study area in Dickey-Sargent counties (December 31, 1990 memo). Specific yield was calculated from total porosity, laboratory wetted porosity, and fielded wetted porosity. Results of study indicate little difference in specific yield between the zone of pedogenesis and the underlying coarse parent materials. Mean values of specific yield by layer were close to 0.25. Based on this, specific yield for Sheyenne Delta aquifer is 0.25 in the study area.

- Water levels remain relatively stable during the winter when recharge does not occur and evapotranspiration is greatly reduced.

- The average annual irrigation application rate from 1977 through 1996 is 9.7 inches per acre in the western portion of the aquifer (permit application area). Compared to the mid to late 1980s, irrigation water use decreased significantly beginning in 1993, due to wetter, cooler growing seasons. Water-level fluctuations caused by irrigation withdrawals are masked by water-level fluctuations caused by natural variations in recharge and discharge (primarily evapotranspiration) as dictated by changing patterns of climate.

- The State Engineer allocated groundwater with a "sustainable yield" management framework for the Sheyenne Delta aquifer because the annual recharge in many years is relatively large in relation to the volume of water in storage (i.e., water is renewable). The sustainable yield in the Sheyenne Delta aquifer is equal to the long-term average volume of groundwater discharged by evapotranspiration and underflow to the Sheyenne River. "Thus, as water is pumped from the aquifer the volume of water discharged by evapotranspiration and to the Sheyenne River will be diminished. Diminishment of groundwater evapotranspiration requires the decoupling of the plant root zone from the capillary fringe of the water table."

- The Sheyenne Natural Grasslands occupy about 110 square miles in the central part of the Sheyenne Delta aquifer (about 28 percent of the aquifer), from which groundwater withdrawals (pumping) will not likely occur.

- The State Engineer has approved an annual appropriation of 19,123.9 acre-feet from the Sheyenne Delta aquifer. This appropriated volume is 15 percent of the average annual recharge of groundwater in the practical development area of the delta.

- Allocations of appropriation are not made using digital groundwater flow models. Instead, an on-going assessment of aquifer response as related to a specific amount of groundwater development is used. Assessment of aquifer response is accomplished by water-level, water-quality, and water-use monitoring, coupled with an evaluation of climate data, aquifer properties and boundary conditions.

- Recommended the appropriation as long as the right of prior appropriators will not be unduly affect; the proposed means of diversion or construction are adequate; the proposed use of water is beneficial; and the proposed appropriation is in the public interest.

Sieg, C.H. and P.M. Wolken, 1998. Dynamics of a threatened orchid in flooded wetlands (DRAFT): submitted to 16th North Am. Prairie Conference, July 26-29, 1998, Kearny, NE, 21 p.

- One of the three largest metapopulations of the western prairie fringed orchid (*Platanthera praeclara)* occurs on the Sheyenne National Grassland, in southeastern North Dakota. Our study was initiated in 1993 to quantify the effect of flooding on individual orchid plants. A total of 66 plants (33 flowering and 33 vegetative) growing in standing water were permanently marked in 1993; their status was checked at the end of the growing season in 1993 and in subsequent growing seasons (1994-1996). Most (70%) of the flowering plants persisted through the 1993 growing season; those that did not were shorter (P=0.001) and had a higher percentage of their stalk submerged through the growing season ($P<0.02$). Only one vegetative plant persisted through the 1993 growing season. The ability of the flowering plants to persist in standing water was attributed to their greater height which allowed some portion of the plant to remain above the water and produce photosynthates needed to produce next season's shoot bud and immature root system. Flowering plants persisted through the first growing season with as much as 75% of their stalk submerged in water. In 1994, only four plants reappeared; in 1995 only one plant reappeared aboveground. None of the plants that did not persist through 1993 reappeared in 1994 or 1995. By 1996 none of the marked plants were observed aboveground. Although flooding is detrimental to the survival of vegetative plants, its impact must be viewed in a larger context and include data over several years. It is likely that flooding creates suitable moisture conditions on higher landscape positions, provides and important mechanism for seed dispersal, and is one of several natural catastrophic events that plays a significant role in perpetuating these wetland systems and associated species.

4.0 Field Trip

The Sheyenne Delta area, the Sheyenne River valley, and the Sheyenne National Grassland were toured on August 13, 1998. In attendance were Ray Wuolo (Barr Engineering Company), Robert Anfang and Mark Meyers (U.S. Army Corps of Engineers - St. Paul District). A portion of the afternoon tour was led by District Ranger Brian Stots (U.S. Forest Service) and Bill Pearson of the U.S. Fish and Wildlife Service. The route of the tour is shown in Appendix B, along with a log of stops and copies of photographs.

5.0 Analyses of River Stage Changes on Groundwater

The approach to evaluating the effects of the two proposed projects on groundwater levels and groundwater quality in the Sheyenne Delta aquifer was to:

! Review, in detail, previous studies on the geology and hydrogeology of the Sheyenne Delta aquifer and synthesize these studies into a coherent conceptual understanding of how groundwater flows and interacts with changes in river stage, precipitation, evapotranspiration, etc. Copies of reports that describe these previous studies were provided to Barr Engineering Company by the USACOE. Additional resources were also sought out, such as bibliographies and the Internet.

! Construct a series of “profile models” of groundwater flow, roughly perpendicular to the Sheyenne River, parallel to regional groundwater flow directions, and spaced across the Sheyenne Delta aquifer. The computer code MODFLOW and the pre- and post-processor ModIME were used to construct these models.

! The MODFLOW profile models incorporated hydrogeologic parameters that had been measured or estimated by others in previous studies. These parameters are believed to represent typical conditions for each profile model, depending upon where the profile is situated in the aquifer.

! Simulations of the conditions of the two proposed projects were performed using the MODFLOW profile models. Transient simulations were performed because of the fluctuation in river stage levels. The simulation results yielded projections of the change in the water table elevation as a function of distance from the Sheyenne River.

! Maps of the projected maximum extent of water-table change were developed from the MODFLOW results.

The details of this analysis approach are described in this section.

5.1 Conceptual Hydrogeologic Model

The “conceptual hydrogeologic model” is a description of how groundwater in the Sheyenne Delta aquifer is recharged, how groundwater is discharged, where groundwater flows, and how groundwater flow conditions are affected by hydraulic stresses, such as the change in river stage of the Sheyenne River. The conceptual hydrogeologic model is also a description of what factors are most important when considering the analysis of groundwater flow and what factors can be neglected without sacrificing confidence in predictions. The conceptual hydrogeologic model states the assumptions that become the basis for the computer models.

5.1.1 Recharge to the Aquifer

Previous studies in the area indicate that water enters the Sheyenne Delta aquifer by: (1) infiltrating precipitation and snowmelt; (2) losses from drainage ditches (where the elevation of the water in the ditch is above the elevation of the water table); and (3) through “bank storage”, which is a temporary discharge from the river to the alluvium and nearby portions of the Sheyenne Delta aquifer during periods of elevated river stage.

The Sheyenne Delta aquifer does not receive substantive amounts of water from underflow, originating beyond the limits of the aquifer. The lateral boundaries of the Sheyenne Delta aquifer are relatively well defined - the Delta is bounded by glacial drift on the west and south and grades into lacustrine sediments in the east and north (Strobel and Radig, 1997). The Sheyenne Delta aquifer may receive small quantities of water from the underlying Dakota Sandstone aquifer, which is under artesian pressure, but only through uncontrolled Dakota Sandstone wells, which yield sodium-sulfate water at an unpumped rate of about 10 gpm (Armstrong, 1982; Hopkins, 1996). A clayey till deposit of up to 260 feet thick (Strobel and Radig, 1997) essentially eliminates direct hydraulic connection between the Dakota Sandstone and the overlying Sheyenne Delta aquifer. Highly plastic, dense clays of Lake Agassiz deposits are found at depths of about 100 feet except in the Sheyenne River valley. These clay deposits probably represent the lake-floor sediments of glacial Lake Agassiz. The thickness ranges from 6 to 24 feet and averages 49 feet. They have a very low transmissivity and function as lower confining beds in the groundwater flow system (Downey and Paulson, 1974).

The Sheyenne Delta aquifer contains an estimated 4 million acre-feet of ground water in storage and receives about 50,000 acre-feet of recharge during a year of average precipitation (Baker and Paulson, 1974). The area receives about 20 inches of precipitation annually, of which about three fourths occurs during the May through October growing season. Somewhat more than 82 percent of the annual evaporation (about 30 inches) also occurs during the same period (Armstrong, 1981).

The water table is usually lowest in late winter, just before the spring thaw. During spring thaw, there is usually a sharp rise in the water table and the yearly high often occurs within a month or two after the yearly low, changing from 5 to 10 feet below ground surface to 1 to 5 feet below ground surface during April. Following the high in spring or early summer, the water levels generally decline through the summer, fall, and winter. However, unusually large amounts of precipitation in the summer or fall will cause a lessening in the rate of decline or may even produce slight rises in water levels. The water table elevations change little during frozen winter months (Strobel and Radig, 1997). Winter precipitation has little or no immediate effect because the frost in the ground impedes the infiltration of water. During the winter, there is little precipitation and what precipitation that does fall is mainly in the form of snow (Baker and Paulson, 1974).

Natural surface drainage in the Lake Agassiz Plain is nearly nonexistent except near the Sheyenne River, which flows through the Sheyenne Delta. Short tributaries to the Sheyenne River have formed, but they only carry runoff for short periods following large storms (Armstrong, 1982). Topography strongly affects the focus of recharge in the aquifer; the largest water level rises in the aquifer are associated with low-relief areas, where rapid infiltration of snowmelt, runoff, and precipitation can take place. Snowmelt and precipitation infiltrate into the aquifer in low-relief areas during early spring and produced a rise in water levels. Snowmelt originating in the upland areas accumulates in depressions from surface runoff because of the inability to infiltrate through the frost zone. Ponded water in depressions infiltrates downward to the saturated zone after the frost zone dissipates (Shaver, 1998). Snowmelt and precipitation in high-relief areas, typically in areas near the river, either travel as surface runoff to low-relief areas or to the river or infiltrate to the water table and flow in the direction of the steep hydraulic gradient toward the river. Delayed recharge may be taking place in areas with thicker unsaturated deposits, due to delayed recharge percolation to the water table (Strobel and Radig, 1997).

According to Bluemle (1979), the pattern of eolian activity and resultant distribution of dunes on the Sheyenne Delta seems to be controlled by the presence or absence of a layer of clay that is less than a foot thick in most places where it is present on top of the ground. Wherever the clay is present, it forms a protective seal, effectively preventing wind erosion; where it is lacking, the sand is free to blow. Bluemle (1979) hypothesizes that groundwater discharge has carried the clay upward, apparently from buried layers of turbidity-current sediment, and deposited it on the surface. We find this to not be a credible explanation for the clay in depressions; it is more likely a combination of eolian and fluvial deposition. In some places, the wind has scoured to the water table, which also act as a barrier to further downward erosion by the wind.

According to Shaver (1998), summer precipitation events generally are not large enough to overcome soil-moisture deficits and generate recharge. Water that infiltrates the soil must first satisfy field moisture requirements. The excess percolates downward to the saturated zone in which the water moves laterally toward areas of discharge along the River and Delta front, which are at low elevations (Downey and Paulson, 1974). Occasionally during the fall, precipitation exceeds both evapotranspiration and soil-moisture deficits and recharge takes place. Even when recharge does not occur during the fall, soil-moisture deficits generally are reduced, significantly affecting the magnitude of the following spring's recharge event. Depth to the water table is generally less than 8 feet. The capillary fringe of water table and root zone are coupled above this depth. As a result, natural discharge from the Sheyenne Delta aquifer is due, in large part, to evapotranspiration.

Whereas most of the recharge to the aquifer takes place during the spring, the annual average recharge rate over the Sheyenne Delta aquifer was estimated by Armstrong (1981) at 4 to 8 inches, through the calibration of a single-layer digital groundwater flow model.

5.1.2 Discharge from the Aquifer

Of the 6 to 8 inches of normal-year infiltration, 1 to 3 inches reaches the Sheyenne River as baseflow and the remainder is lost to evapotranspiration (Armstrong, 1981). Pumping of groundwater from wells is also a discharge mechanism, although it likely pales in comparison to natural mechanisms (Baker, 1967), although the number of application permits to withdraw water from the Sheyenne Delta aquifer for irrigation has increased markedly (Hopkins, 1996). The State Engineer has approved an annual appropriation of 19,123.9 acre-feet from the Sheyenne Delta aquifer. This appropriated volume is 15 percent of the average annual recharge of groundwater in the practical development area of the Delta (Shaver, 1998). Shallow, high-production irrigation wells and crops such as corn and potatoes (that thrive in coarser-grained irrigated soils) are found most commonly on the western part of the Delta (Cowdery and Goff, 1994). The major areas of groundwater discharge are in the Sheyenne River and its tributaries, the Sheyenne Delta scarp, several manmade drains on the upland surface of the Delta, and where the water table is near land surface, by evapotranspiration (Downey and Paulson, 1974).

The Sheyenne River winds its way eastward through the delta for a distance of about 52 river miles, effectively dividing the aquifer into north and south units. Paulson (1964) had indicated a marked increase in river discharge eastward through most of the aquifer as a result of groundwater inflow. The discharge measurements by Paulson (1964) were limited to the mainstem and did not include tributaries directly. The Sheyenne River is a gaining stream throughout the delta area of Ransom and Richland Counties. The gain in Ransom county was about 14 cfs in the fall of 1963. Precipitation in 1963 was about 90 percent of normal so the measured gain probably was lower than would be expected during a year of normal precipitation (Paulson, 1964).

Low-flow stream measurements were made in May and August 1972 by Downey and Paulson (1974)—most in tributaries. The measurements indicated an increase in river discharge of 109 cfs (cubic feet per second) and 29.4 cfs respectively. The large difference between the two discharge increases is attributed mainly to evaporation, which normally is low in May but near maximum in August. Some of the difference is attributed to steeper hydraulic gradients in May, resulting from recharging spring rains and snowmelt, with consequently higher rates of groundwater movement. Of the 109 cfs increase in discharge measured in May 1972, 17.4 cfs was measured in the tributaries. Of the 29.4 cfs increase in August, 7.6 cfs was in the tributaries. These data indicate that about 84 percent of the discharge measured in May and about 73 percent measured in August was received as seepage inflow through the channel of the Sheyenne River. Furthermore, measurements were made at several points along the lengths of the tributaries and the data showed a fairly uniform increase in discharge, as would be expected in a normal groundwater discharge pattern.

Shaver (1998) indicates that discharge to the Sheyenne River is negligible along the western flank of the aquifer. A "20- to 40-foot difference in water-level elevations between the westernmost irrigation wells and the Sheyenne River...indicates a poor hydraulic connection between the aquifer and the river in this area." In this area, the Sheyenne River is incised into the glacial till.

Discharge of groundwater as springs can take place where the elevation of the ground surface is below the elevation of the water table. In most locations, evapotranspiration keeps the groundwater from "daylighting" but in areas where the topography changes substantially over a short distance (such as in eroded drainages, along the northern scarp of the delta, and in the Sheyenne River valley) springs can form. Many of the springs in the Sheyenne River valley appear to be surface expressions of groundwater at the head of gullies. In some of these gullies, tributaries form. Near the River, fens are present, where the water table is above the ground surface and upwelling conditions are attained. Springs that issue in the Sheyenne River valley or in the tributaries of the Sheyenne River are contributors to the base flow of the river. Discharge of groundwater through numerous springs along the eastern edge of the Delta may be 5 to 10 times as great as the fall and winter discharge to the Sheyenne River. Even so, annual discharge through springs is probably less than half of the estimated annual recharge (Baker and Paulson, 1967).

It is important to note that flow rates of springs issuing above the surface elevation of the Sheyenne River are independent of the elevation of the River. This includes seepage faces that develop in the river bank.

The average annual maximum potential evaporation rate in an area that includes the Sheyenne Delta aquifer is about 30 inches (Armstrong, 1981). A range of values for maximum evapotranspiration from 25 to 35 inches per year was found by Armstrong (1981) to be in balance with the range of recharge rates (@ 20 inches per year) that he used in his model. Maximum depths of 6 to 10 feet for the effective evapotranspiration proved to fit best with observed steady-state conditions. Others, modeling settings similar to the Delta in North Dakota, came up with recharge ranges of between 7 and 8.25 inches per year and effective evapotranspiration depth limits of 8 feet. Shaver (1998) indicates that within about 2 to 3 miles of the Sheyenne River in northern Ransom and Richland counties, the hydraulic gradient of the aquifer is about 20 to 60 feet per mile (0.0038 to 0.0114). In these areas, depths to water table commonly are greater than 8 feet and the capillary fringe of the water table and root zone are uncoupled. The average depth limit of evapotranspiration in the Armstrong (1981) model was set at 8 feet. Recharge was set at 7.4 inches per year, giving the best fit of simulated to measured water levels during calibration, using the assumed values of evapotranspiration (Armstrong, 1981).

Soil developed on the aquifer is porous and permeable. Armstrong (1981) cites a vertical permeability equivalent to infiltration rates of 2 to 6.3 inches per hour in soils similar to those in the Delta. These rates are sufficiently high to preclude most runoff except when the ground is frozen, during extremely intense precipitation periods, or when the water table is very close to the land surface.

5.1.3 Bank Storage

Bank storage refers to the process in which there is a temporary reversal of hydraulic gradient and groundwater flow direction immediately adjacent to a rising river, causing water from the river to flow into the aquifer, rather than from the aquifer into the river. This is a short-term process that typically takes place during spring thaw or during rainfall events that cause a river stage to rise. Once the river stage begins to drop, normal groundwater flow directions are approached and the river water that was stored in the river bank is discharged back into the river. Thus, it is a process of both recharge to the aquifer and discharge from the aquifer.

The concept of bank storage, as it applies to the Sheyenne River, is shown schematically on Figure 6. Under most conditions and in most locations, groundwater from the Sheyenne Delta aquifer discharges into the Sheyenne River. During flood conditions, the river rises above the adjacent groundwater and flow is reversed from the river and into the aquifer. Aquifer storage is filled and the aquifer and the river slowly work to reach a new equilibrium (the time required to reach this equilibrium is measured by the aquifer's specific yield, which is an unconfined storage coefficient). For unconfined (water table) aquifers, it typically takes much longer for a new equilibrium (steady-state condition) to be reached than the period of time that the river stage is abnormally high (even in the spring). "Stagnation points" develop in the aquifer on either side of the river channel, which represent low points in the water-table surface. On the river-side of the stagnation point, water flows from the river and into the aquifer. On the aquifer-side of the stagnation point, groundwater flow remains toward the river, although flow rates are lowered in response to a lower hydraulic gradient.

When the river stage begins to drop, hydraulic gradients begin to shift once again toward the river and river water that had flowed into the aquifer now flows back into the river. In other words, the "stored" water in the river "bank" is released back into the river.

Strobel and Radig (1997) observed temporal reversals of flow in some locations near the Sheyenne River during spring runoff, which they attributed to bank storage effects. These reversals were not long-lived, lasting only a few weeks.

5.1.4 Aquifer Hydraulic Conductivity

Hydraulic conductivity (similar to permeability) is a measure of a material's ability to transmit water under a hydraulic gradient. It is probably the single most important parameter controlling groundwater flow and was included in a fundamental empirical equation derived by d'Arcy and which bears the name Darcy's Law:

q = K x Îh/ÎL

where: K is the hydraulic conductivity, with units of length per time;
Îh is the change in hydraulic head (water level) per length (ÎL); and

q is the volumetric flow rate per unit area of material with units of length per time

Hydraulic conductivity can be measured through various types of tests, such as slug tests and permeameter tests. It can also be calculated from pumping (aquifer) tests and estimated from grain-size analyses (such as Hazen's method). In general, the coarser the material, the higher the hydraulic conductivity. A clay has a much lower hydraulic conductivity value than does a sand and a gravel has a very high value of hydraulic conductivity.

Transmissivity is also a measure of an aquifer material's ability to transmit water but it generally applies to the aquifer's entire thickness rather than a unit volume or unit area. Transmissivity is typically measured through pumping tests, where water levels in an aquifer are monitored and analytical methods are used to calculated transmissivity. Hydraulic conductivity and transmissivity are related through the following equation:

$$T = K \times b$$

where: K is the hydraulic conductivity, with units of length per time;
b is the aquifer's saturated thickness, with units of length; and
T is the transmissivity, with units of length-squared per time.

Obviously, if transmissivity is measured/calculated and the aquifer's saturated thickness is known, the hydraulic conductivity can be easily estimated.

Progradation of the Delta into Lake Agassiz resulted in a general trend of increasing grain size in both the upward and beachward directions. Hydraulic conductivity in the Sheyenne Delta aquifer decreases from the southwest to the northeast as the deposits grade from predominantly sand in the southwest to predominantly silt and clay in the northeast, with a corresponding decrease in hydraulic conductivity. The sand is primarily very fine to fine grained and grades northeastward into silt and clay through a transition zone of interbedded sand and silt (Downey and Paulson, 1974). This trend is consistent with the grain-size distribution expected in a delta that was formed from a river discharging into glacial Lake Agassiz from the southwest. Downey and Paulson (1974) conducted aquifer tests at 3 locations on the Delta, measured hydraulic conductivity in 25 core samples, and applied a water-table profile-analysis method at various locations to produce a map of hydraulic conductivities for the aquifer. This map was digitized and geostatistically analyzed for the purpose of this study and is shown on Figure 7.

In Richland County, the delta deposits can be divided into three units: (1) a lower unit of silt interbedded with clay and sand, which is thickest near the eastern margin of the Delta and thins westward; (2) an upper unit of well-sorted sand, which is thickest in the west and thins eastward; and (3) a thin layer of wind-blown sand, which covers the entire Delta. The lower silty unit is more than 150 feet thick at the eastern edge of the delta, less than 50 feet thick near the Richland-Ransom County boundary, and is entirely absent near the western edge of the delta in Ransom County (Baker and Paulson, 1967).

The upper unit of well-sorted sand is as much as 100 feet thick near the Richland-Ransom County boundary, and is entirely absent near the eastern edge of the Delta in Ransom County. Its average thickness in Richland County is about 60 feet. The grain size of the sand generally decreases eastward from medium and coarse along the Richland Ransom County boundary to very fine in the eastern part of the Delta near Walcott (Baker and Paulson, 1967).

The thin layer of wind-blown sand, which covers the entire Delta, is generally less than 10 feet but may be as much as 50 feet in the highest dunes. The upper unit of well-sorted deltaic sand and the overlying deposits of wind-blown sand form the main part of the Sheyenne Delta aquifer—the lower silt unit is generally too fine grained to yield water to wells (Baker and Paulson, 1967).

Transmissivities in the Sheyenne Delta aquifer range from about 200 feet squared per day (1,500 gallons per day per foot) in the silt/clay facies to about 1,400 feet squared per day (10,500 gallons per day per foot) in the sand facies (Downey and Paulson, 1974). Estimates of transmissivity from grain size (5 locations) resulted in 30,000 gpd/ft (gallons per day per foot) near the Richland-Ransom County boundary where the upper sand unit is more than 100 feet thick to less than 500 gpd/ft in the southeastern part of the delta where the upper unit is absent (Baker and Paulson, 1967). The deposits range in thickness from 49 to 140 feet and average 97 feet. The entire Delta thins to the west as the Lake Agassiz basin approaches the surface.

The deltaic deposits in the Sheyenne River valley have been reworked by the meandering, erosive nature of the river. Locally derived sand and gravel from the delta has been mixed with finer grained materials transported by the river from till-dominated areas upstream of the Delta. Downey and Paulson (1974) developed several cross sections perpendicular to the Sheyenne River and concluded that the deltaic deposits have been completely reworked in the Sheyenne River valley throughout its course in the Delta. Downey and Paulson (1974) consider the reworked valley deposits to be hydraulically part of the Sheyenne Delta aquifer but they represent a zone of somewhat lower hydraulic conductivity.

Armstrong (1982) noted that yields form individual wells should range from a few gallons per minute near the western edge and the alluvial areas to about 1,000 gpm in areas where more than 35 feet of gravelly sand exists. Variations in yield within short distances may be large, as discovered by a few prospective irrigators who have drilled two to five test holes in the same quarter section before finding a sufficient thickness to yield enough water to supply a pivot system. However, most of the area will yield more than 250 gpm. The yield range for most of the Sheyenne Delta aquifer is 250 to 1,000 gpm because variations in thickness and transmissivity make closer estimates impractical.

Shaver (1998) indicated that specific capacity tests were conducted by drilling contractors on 23 irrigation wells located in an application evaluation area (test duration ranged from 1 to 100 hours). Transmissivity was estimated using the method of Walton (1970). Estimated transmissivities ranged from 1,700 ft^2/day to about 12,000 ft^2/day, with a mean of 5,400 ft^2/day.

5.1.5 Aquifer Base Elevation

The Sheyenne Delta aquifer is unconfined (i.e. the piezometric surface and the water table are the same). The saturated thickness of the aquifer is therefore a function of the water-table elevation and the base elevation of the aquifer at any given location. The Sheyenne Delta aquifer has a reported mean saturated thickness of 41 feet in Ransom and Sargent Counties (Armstrong, 1982).

Pleistocene lacustrine clays about 100 feet thick underlie the Sheyenne Delta aquifer throughout (Downey and Paulson, 1974). The clays, which are plastic and have low hydraulic conductivity, form a relatively impermeable basal unit to the aquifer. The contact between the aquifer and the lacustrine clays is poorly defined because the prograding delta deposited over its own bottomset beds, which have essentially the same composition as the lacustrine clays (Baker, 1967). The transmissive delta deposits range in thickness from 49 to 140 feet and average 97 feet, with the entire delta thinning to the west as the Lake Agassiz basin approaches the surface (Downey and Paulson, 1974).

None of the previous studies has a map or other quantitative description of the base elevation of the Sheyenne Delta aquifer. Downey and Paulson (1974) and Armstrong (1981) used transmissivity, rather than hydraulic conductivity, in their digital modeling and therefore did not need to compute base elevation or saturated thickness. However, Downey and Paulson (1974) did make an attempt to delineate the contact between Lake Agassiz lacustrine deposits and deltatic deposits, though they failed to differentiate between the low-transmissive basal deltaic deposits and the highly transmissive deltaic sands.

For this study, we developed a map of the base elevation of the transmissive portion of the Sheyenne Delta aquifer from three sources: selected boring logs in Baker (1967); Plate 2 of Downey and Paulson (1974); and selected borings logs in Armstrong (1979). A Surfer® grid of the base elevation data was made, from which elevations along the model profiles were interpolated. The map of the base elevation of the Sheyenne Delta aquifer is on Figure 8.

The base elevation of the aquifer generally slopes from southwest to northeast, following the lacustrine clay surface of the Lake Agassiz deposits. The elevation changes from over 310 meters (1,017 feet, MSL) southeast of Lisbon to about 260 meters (853 feet, MSL) southwest of Kindred; a distance of about 30,000 meters. While not as flat as the overall ground surface topography (excluding local depressions and dunes), the aquifer base does not appear to have much relief. This is consistent with the depositional environment in which the deltaic sands were deposited.

5.1.6 Groundwater Flow Direction and Water-Level Fluctuations

Regional groundwater flow is from upland areas to the River, at both high and low flood/recharge conditions. The steepest hydraulic gradients are beneath the bluffs on each side of the river valley. Within about two to three miles of the Sheyenne River in northern Ransom and Richland counties, the hydraulic gradient of the aquifer is about 20 to 60 feet per mile (0.0038 to 0.0114) (Shaver, 1998). Two to five miles beyond the river valley, regional gradients become low and local gradients, which are toward individual low areas where evapotranspiration is greatest, mask regional trends (Armstrong, 1982). The Sheyenne River is eroded as much as 120 feet below the surface of deposition of the deltaic sediments. Accordingly, the water table slopes toward the Sheyenne River valley and toward the Delta edges (Baker, 1967). Because a surface-water divide and a groundwater drainage divide are near the Sheyenne River along the western edge of the Delta, only a relatively small amount of groundwater drains westward to the River (Paulson, 1964; Shaver, 1998).

Reversals of groundwater flow very near the River were inferred from water-level data during high stage conditions in the River (i.e. bank storage) by Strobel and Radig (1997). These reversals were “temporary” (less than one month) in duration and very localized near the river (less than one mile from River). Overall hydraulic gradients to the Sheyenne River decreased slightly during this period, due both to higher river stage and to increased infiltration over the aquifer. There is evidence of "ridges" of high groundwater levels bordering both sides of the Sheyenne River valley. These ridges appear to be related lithologic changes in the aquifer and residuals from previous periods of recharge (Downey and Paulson, 1974).

Strobel and Radig (1997) estimate that high stage levels on the Sheyenne River in July and August 1993 probably caused water-table gradients near the River to reverse and water from the River flowed into the aquifer as temporary bank storage. "Direct effects of the 1993 flood on water levels in the aquifer probably were limited to the area adjacent to the river." "However, excessive precipitation associated with the flood probably affected water levels throughout the aquifer. Water levels in two observation wells in the aquifer indicate that the water table generally was about 2 feet higher during the fall and winter of 1994 than during the fall and winter of 1993." (Strobel and Radig, 1997, p. 35).

The water table fluctuates considerably but most of the time and in most places it is less than 10 feet below the surface. The water table usually is lowest in late winter, just before the spring thaw. During spring thaw there is usually a sharp rise in the water table and the yearly high often occurs within a month or two after the yearly low, changing from 5 to 10 feet below ground surface to 1 -5 feet below ground surface during April. Following the high in spring or early summer, the water levels generally decline through the summer, fall, and winter. However, unusually large amounts of precipitation in the summer or fall will cause a lessening in the rate of decline or may even produce slight rises in water levels (Baker, 1967). The water-table elevations change little during frozen winter months (Strobel and Radig, 1997). Water-level fluctuations caused by irrigation withdrawals are masked by water-level fluctuations caused by natural variations in recharge and discharge (primarily evapotranspiration) as dictated by changing patterns of climate (Shaver, 1998).

Groundwater divides were delineated by Paulson (1964) in areas of nearly flat hydraulic gradient north and south of the Sheyenne River. These boundaries roughly parallel the Sheyenne River and became boundaries for the finite-difference flow models developed for the studies of Downey and Paulson (1974) and Armstrong (1981). The divides and flow paths (interpreted by Paulson, 1964) are shown on Figure 9.

5.1.7 Aquifer Storage Parameters

Aquifer storage parameters are only important when transient (non-steady state) effects are considered. For an unconfined aquifer, the specific yield (S_y) is the storage parameter of importance. As a rule of thumb, the larger the specific yield, the longer it takes for an aquifer stress (such as an increase in the stage elevation of a river) to manifest itself as a change in water level in a hydraulically-connected aquifer. This is because higher specific yield values indicate a larger effective porosity that must be filled by the water as the phreatic surface rises. For unconfined medium-sand aquifers, a typical range for specific yield is 0.16 to 0.46 (mean of 0.32) and for unconfined gravel aquifers a typical range is 0.17 to 0.44 (mean 0.24) (Morris and Johnson, 1967).

Porosity of cores of deltaic sand deposits that were examined by Baker and Paulson (1967) ranged from 40 to 48 percent and averaged 43 percent. Specific yield of four cores ranged from 25 to 40 percent (Baker and Paulson, 1967 noted that these values seemed "rather high" for deltaic sand deposits as a whole but may be representative for the coarser facies). They estimated the specific yield for the upper part of the deposits by comparing the rise in water levels in observation wells with precipitation. An average rise of 3.4 feet in 22 wells was attributed to April rains and to a lesser extent by snow melt. The average storage for the upper deposits was estimated to be no greater than 10 percent, but that this value was too low to be representative of the entire deltaic strata.

Armstrong (1982) estimates the specific yield (by unknown means and from unknown data) at 0.15. William M. Schuh, Hydrologist Manger, NDSWC summarized storativity calculations for Hecla, Hamar, and Ulen soils (5 sites) in the Oakes aquifer study area in Dickey-Sargent counties (December 31, 1990 memo cited by Shaver, 1998). Specific yield was calculated from total porosity, laboratory wetted porosity, and fielded wetted porosity. Results of this study indicated little difference in specific yield between the zone of pedogenesis and the underlying coarse parent materials. Mean values of specific yield by layer were close to 0.25. Based on this, Shaver (1998) estimated a specific yield for Sheyenne Delta aquifer at 0.25.

Only one pumping test performed in the Sheyenne Delta aquifer has produced a specific yield value that was believed by Downey and Paulson (1974) to be valid (17% or 0.17)—the others were much too low because of incomplete drainage. Downey and Paulson (1974) and Armstrong (1981) rounded this value up to 0.20. Specific yield values from properly conducted pumping tests of sufficient duration to extend past the gravity-drainage period are the most reliable values for unconfined aquifers.

5.2 Analysis Methods

This section describes how the information and data summarized in the conceptual hydrogeologic model were used to make quantitative predictions of the effects of the Baldhill Pool raise and the Devils Lake Outlet project on groundwater in the Sheyenne Delta aquifer.

5.2.1 Hydraulic Effects

Hydraulic effects of the two projects on groundwater levels were analyzed by developing numerical profile models along six non-linear cross sections through the Sheyenne Delta aquifer using the U.S. Geological Survey's finite-difference groundwater flow code MODFLOW (McDonald and Harbaugh, 1988; Harbaugh and McDonald, 1996). The cross sections are non-linear because they are oriented along groundwater flow paths, defined by Paulson (1964).

The profile-modeling approach was chosen over analytical analyses methods because profile modeling was able to account for changes in aquifer characteristics such as hydraulic conductivity and aquifer thickness, as well as spatial changes in topography and evapotranspiration. All of these parameters were believed to be important considerations at the start of this study. The alternative to profile modeling is a full, three-dimensional computer simulation of the aquifer. While certainly a worthwhile endeavor, three-dimensional modeling of the aquifer would be expensive and computationally demanding, whereas profile modeling is relatively quick. The advantage of the profile-modeling approach is that many more simulations (including transient simulations) could be performed with only a small loss in the "realism" of the simulation.

The locations of the six profile sections that were modeled are shown on Figure 10. The profiles extend from the groundwater divide of Paulson (1964) to the center of the Sheyenne River, which is a hydraulic boundary. Profiles were not constructed to simulate areas north of the river because the flow path north of the river is much shorter, and because the area where orchids grow is south of the River. It is considered reasonable to assume that the groundwater effects on the north side of the river would be similar to those described for the south side of the river. A profile section was not placed between Section 5 and Section 6 because such a section would roughly coincide with the extensive north-flowing drainage. This north-flowing drainage represents a hydraulic boundary condition that would render the groundwater levels in its vicinity insensitive to stage changes in the Sheyenne River.

5.2.1.1 Description of Flow Equations

The three-dimensional groundwater flow equation is:

$$\frac{\partial}{\partial x}\left(K_x\frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y\frac{\partial h}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z\frac{\partial h}{\partial z}\right) = S_s\frac{\partial h}{\partial t} - R$$

The partial derivatives on the left side of the equation simply state that: (1) hydraulic conductivity (K) can be a tensor (i.e. it can vary, depending upon direction X, Y, or Z) and (2) hydraulic head (h) is a second partial derivative of the three principal directions. The left side of the equation equals zero for a steady-state simulation. The right side of the equation represents the water placed into or taken out of storage as a function of time (t). R is a general sink or source term.

For unconfined flow, it is assumed that T = Kh (i.e. transmissivity equals hydraulic conductivity times aquifer thickness). Further, if flow is being calculated along a flow path, then (by definition) there is no component of flow perpendicular to the stream line. If the streamline is assumed to be along X and Y is perpendicular to X, then the equation above simplifies to:

$$\frac{\partial}{\partial x}\left(K_x\frac{\partial h^2}{\partial x}\right) + \frac{\partial}{\partial z}\left(K_z\frac{\partial h^2}{\partial z}\right) = 2S_y\frac{\partial h}{\partial t} - R$$

S_y is the specific yield. It is this equation in a profile model that is solved numerically. In the case of MODFLOW, the differential equation is solved by a finite-difference approximation.

5.2.1.2 MODFLOW Profile Model

Each of the six profile models (one for each section) consists of 1 cell wide (width of one meter, perpendicular to the flow direction), 193 cells long, and 8 layers tall. Layer 1 (top layer) is of indeterminant thickness because the system is unconfined. The one-cell width is a standard profile modeling practice (Anderson and Woessner, 1992). Layers 2 through 6 are 5 meters thick and Layers 7 and 8 are 10 meters thick. All layers are horizontal. Because each profile has the same number of cells in the direction of flow but each is of different length, the cell length varies, depending on the section. The cell lengths for Sections 1 through 6, respectively are: 12.9 meters;

14.5 meters; 53 meters; 97.8 meters; 80.2 meters; and 90.6 meters. A portion of a typical profile model is shown on Figure 11.

The profile model orientation used in this study is termed a "slice" orientation because it is a vertical slice along a flow path. With the slice orientation, no adjustment to hydraulic conductivity, specific yield, or recharge is needed to compensate for the slicing of the aquifer into a section (Anderson and Woessner, 1992). The "moving boundary" problem of a varying water table is not at issue either since the layers are allowed to convert from confined to unconfined if the water table drops into a given layer. Recharge is applied to the uppermost active node (nodes that are not saturated are made inactive). The MODFLOW grid was designed and the parameters were entered into the model using the integrated modeling environment ModIME.

5.2.1.3 Initial Conditions

The difference between the two events is that the Baldhill Pool raise scenario is a randomly-timed flood event of approximately 70 days duration whereas the Devil's Lake outlet has a recurring, seven-month long duration. Because of the difference in the types of scenarios represented by these events, different approaches were required in setting up the baseline conditions.

It could reasonably be assumed that the recharge and evapotranspiration conditions would remain constant during the flood event simulation period. Therefore, a steady-state condition, with typical values for recharge and evapotranspiration and a river stage equal to the starting stage for the flood event was chosen for setting the initial conditions for the Baldhill Pool raise simulation. The baseline case used the steady-state heads for initial conditions and imposed a series of river stage changes typical of a 100-year flood under current conditions. The effects of the Baldhill Pool raise were then simulated using a second series of river stage changes reflecting the effects of the pool raise (see Figure 2.) In this way, the effects of differences in river stage throughout the flood event could be compared directly. This approach isolates the effect of interest: the only boundary condition that is changing in the simulation is the river stage. Consequently, the effects of different time-varying river stages as caused by the Baldhill Pool raise versus the baseline condition can be determined directly by comparing the results of the two simulations.

In contrast, the Devils Lake outlet scenario is on a time scale (seven months) over which variations in recharge rate, evapotranspiration rate, and river stage could not reasonably be assumed as constant and must therefore be incorporated in the simulation. Since the system is dynamic (e.g., see Figure F-2) and the question is "what are the effects of an increase in discharge over a specified period of time in a typical year" the first task was to determine what the typical year looks like. If the baseline transient simulation starts from an arbitrary steady-state condition, part of the water level response might reflect the system moving toward equilibrium with its new boundary conditions. To prevent this, the simulation of the typical year was run several times in succession, with the final water levels from one year forming the starting conditions for the following year. It was found that after about four or five years, a pattern was set up in which the water levels at the end of the simulation were approximately equal to those from the beginning of the simulation, which was the desired effect. In this way, differences between the baseline response and the response caused by the higher river stages due to operation of the Devils Lake outlet could be isolated from other causes.

5.2.1.4 Transient Analysis

The annual river stage rise and groundwater level rise share a common cause: spring thaw releasing water trapped as snow and frost and somewhat higher-than average precipitation in April and May (Baker and Paulson, 1967; Strobel and Radig, 1997). In other words, groundwater levels rise naturally in the spring and these rises are generally not because the stage level of the Sheyenne River is rising (Strobel and Radig, 1997).

In order to determine the effects of the proposed projects on a typical spring cycle, it was necessary to simulate the superposition of elevated river stage (above and beyond the typical effects) on the typical spring cycle and determine the effects in terms of deviations from the typical condition. As such, this is a transient (time-dependent) problem. The question is: how much additional change in groundwater level is predicted to result from the additional increase in river stage?

5.2.2 Water Quality Effects

The effects of excursion of Sheyenne River water into the Sheyenne Delta aquifer were not directly evaluated in this study. Instead, hydraulic effects were evaluated, which could be used to place an extremely conservative limit on the potential extent of excursion of Sheyenne River water into the aquifer. Principally, the distance from the River where the predicted water-level increases would be zero was conservatively taken as the maximum extent of excursion of river water. If the results suggested, further and more detailed analysis might be warranted.

5.3 Data and Assumptions Used in MODFLOW Analyses

The sources of hydrogeologic data were described in Section 5.1. Ranges of reported values for water budget factors and aquifer parameters are summarized in Table 1. Values used in the modeling are discussed below, along with additional details. Data specific to each project are discussed in the following subsections.

5.3.1 Hydraulic Conductivity, Aquifer Base Elevation, and Specific Yield

Hydraulic conductivity values for the Sheyenne Delta aquifer were based on Plate 3 of Downey and Paulson (1974). As described previously, a digital Surfer® map was constructed from these data and is shown on Figure 7. Aquifer base elevation varied across the site and was gleaned from various sources, as described in Section 5.1. Figure 8 shows the digital Surfer® map that resulted from that compilation. The grid values that result from the geostatistical routines that went into making Figures 7 and 8 became the basis for assigning parameters to profile models.

Once the six profiles were delineated, the cell coordinates (UTM NAD 27) along each profile were determined using ArcView® GIS (geographic information system). The Surfer® grids for hydraulic conductivity and aquifer base elevation are also in UTM NAD 27 coordinates. Using a residual query technique in Surfer®, the hydraulic conductivity and aquifer base elevation for each grid cell along each profile were assigned. For those cells (principally in Layers 7 and 8) that had elevations predominantly below the aquifer base elevation, a hydraulic conductivity of 0.1 meters/day was assigned to represent the underlying clay (see Appendix F for additional details). A vertical anisotropy value of 0.1 was used (i.e. the vertical hydraulic conductivity was assumed to be 10 percent of the horizontal hydraulic conductivity). This is a value typically used to model sand aquifers (Anderson and Woessner, 1992).

The specific yield value used in all simulations was 0.15, which is slightly lower than the 0.2 value used by Downey and Paulson (1974). This is considered a conservative value. A storage coefficient value of .0001 was used for layers that did not contain the phreatic surface. These storage parameters are deemed to be on the low side and will therefore yield a “worse-case” transient response to increases in river stage.

5.3.2 Recharge

5.3.2.1 Devils Lake Outlet

For the simulations of the Devils Lake Outlet, typical monthly precipitation values were acquired from the Northern Prairie Wildlife Research Center via the Internet at:

http://www.npwrc.usgs.gov/resource/othrdata/climate.

The data are included in Appendix C. Since several previous studies (e.g., Downey and Paulson, 1974; Armstrong, 1982; Strobel and Radig, 1997) indicate that most of the recharge takes place immediately following frost-out and during the spring months precipitation falling in December through February were not applied until March to simulate the effects of frost preventing infiltration.

5.3.2.2 Baldhill Pool Raise

The USACOE provided hydrographs for the Lisbon gage and Kindred gage showing river stages throughout a series of floods with and without the Baldhill Pool raise (Figure 2). In general, the effect of the Baldhill Pool raise would be to lower the peak stage of the flood and to prolong its duration. The simulations are based on statistical evaluations of the recorded river stages at the two gages. No direct correlation with precipitation is possible. Since the objective of this project was to determine the effects in terms of deviation from typical conditions, a typical annual precipitation of 497 mm (19.57 in/yr) (Sieg and Wolken, 1998) was applied to both simulations as the recharge value in terms of 497 mm/365 days, or 1.36 mm/day for the 70-day simulation period. Recharge is not a substantially important parameter during this simulation because evapotranspiration essentially cancels out its effect.

5.3.3 Surface Topography

The topography of the ground surface is generally not a parameter in most groundwater models but it was used in this model as a control on spring formation (i.e. where groundwater elevations are higher than the ground surface) and evapotranspiration (which is a function of depth to groundwater at a given location).

Ground surface elevation was obtained from digital elevation maps (DEMs) developed by the U.S. Geological Survey and downloaded from the Internet at http://www.gis.swc.state.nd.us/. These DEMs were converted to UTM NAD 27 coordinates and incorporated into an ArcView® GIS project. Elevations in meters above mean sea level were then obtained for each MODFLOW profile model cell along each section. Spot checks were performed with U.S. Geological Survey 7.5 minute quadrangle maps in the immediate vicinity of where the profile and the Sheyenne River intersected. The accuracy of the elevation data was considered sufficient for the intended use because the modeling was intended to reflect the relatively large vertical difference between the upland areas and the river (a difference of up to 120 feet, Strobel and Radig, 1997, p.7).

For the portion of each profile that transected the Sheyenne River valley, drain cells were placed in the appropriate layer with heads equal to the ground-surface elevation. In this way, seepage and springs could be simulated if the water table elevation in any of these cells exceeded the ground-surface elevation. For the most part, this did not take place during the simulations.

In setting up the drain package input file, no drain invert was specified at an elevation below the maximum river stage for that simulation. For example, on Table F-4, the maximum river stage for the simulation of the Baldhill Pool raise at that cross-section was 317.69 m MSL. This was used as a default invert elevation for those cells in which the surface elevation was lower than this maximum river stage. This was done to prevent a drain cell located near the river, which would be inundated at that maximum river stage, from removing water from the system. This prevents the creation of unrealistic boundary conditions using the drain cells.

5.3.4 Evapotranspiration

The Evaporation Package in MODFLOW was employed in simulating both the Devils Lake Outlet and the Baldhill Pool raise. Three parameters are required: (1) the maximum evapotranspiration potential; (2) the depth below which maximum evaporation no longer takes place; and (3) the depth beyond which the capillary fringe of the water table and the root zones are decoupled and groundwater evapotranspiration ceases (i.e., groundwater ET extraction depth). The ground surface elevation must also be known— this is described in the previous section.

The Evapotranspiration Package assumes an evapotranspiration removal rate equal to the maximum evapotranspiration potential between the ground surface and the depth at which the maximum no longer holds. This value was taken from Downey and Paulson (1974) as 7.16 feet. The depth at which evapotranspiration from the water table ceases was also taken from Downey and Paulson (1974) at 11.25 feet. From 7.16 feet downward to 11.25 feet, the evapotranspiration rate decreases linearly.

5.3.5 Sheyenne River Stage

5.3.5.1 Devils Lake Outlet

Typical monthly discharges and ratings tables for the Sheyenne River at the Lisbon gage and Kindred gage were acquired from the U.S. Geological Survey via the Internet at:

http://water.usgs.gov/cgi-bin/realsta.pl?huc=09020204.

The ratings table contain the information needed to convert from discharge to river stage. The river stage was interpolated between the two gages assuming a linear relationship with river mile. The effects of the Devils Lake outlet were modeled by adding 300 cubic feet per second of discharge to the monthly average values for the months of May through November (Table 2).

5.3.5.2 Baldhill Pool Raise

The USACOE provide stage-elevation curves for the various flood events for the Lisbon and Kindred gage, assuming the Baldhill Pool raise (Figure 2). The river stage was interpolated between the two gages assuming a linear relationship with river mile.

5.3.6 MODFLOW Simulation Criteria

Simulation convergence criteria was generally set at 1 x 10^{-5} meters for the maximum head change between iterations and 0.1 m^3/day for the maximum flux change for any cell between iterations. For the Devils Lake Outlet transient simulations, 12 stress periods of 30 days were used and each time step was 1 day. For the Baldhill Pool raise, each stress period was one day long and there were three equal time steps per stress period.

The Devils Lake Outlet project was assumed to release identical discharges each year for the same duration. A total of 6 years was simulated until it was verified that there was not cumulative, year-to-year carry-over of water level effects. The flood events for the Baldhill Pool raise are random events that do not depend on stage conditions from the previous year. A 70-day simulation period was used for the Baldhill Pool raise.

The BCF2 Block-Centered Flow package was employed in the simulations. The PCG2 congugate block solver was used. An example of the MODFLOW input data files is in Appendix F, along with an example of the hydrographs produced from each simulation.

All modeling was performed on a Pentium® 266 MHZ machine with 64 Mbytes of RAM. A Windows®NT platform was employed.

5.4 MODFLOW Simulation Results

This section describes the results of the MODFLOW simulations for the profile models through the Sheyenne Delta aquifer. Because the simulations are transient, the water level in the aquifer may be different, depending on the particular time step and stress period. An example of a simulated hydrographs for a profile are in Appendix F. The primary focus of this study is the *maximum* increase in the water level due to the particular project. Only the maximum (i.e. "worse-case") simulated increase in water level in the aquifer is emphasized in the following discussions.

The potential effects of the two projects cannot be directly compared because the Devils Lake Outlet operates over a seven-month period whereas the Baldhill Pool raise effects were evaluated with respect to a 70-day-long flood event. In general, the magnitude of river stage change is greater for the Baldhill Pool raise than the Devils Lake Outlet. Consequently, near the river, the maximum groundwater level change is expected to be greater for the Baldhill Pool raise.

5.4.1 Devils Lake Outlet

The maximum simulated increase in the water table as a function of distance from the Sheyenne River is shown on Figure 12 for the six profile sections. These plots represent the maximum likely increase in the water table elevation from the Devils Lake Outlet project. Except for Section 6, water level increases in all other sections are less than 0.1 feet (1.2 inches) at a distance of 1,500 feet from the Sheyenne River. Water level increase along Section 4 drop below 0.1 feet at approximately 750 feet from the River. There is essentially no effect of the Devils Lake Outlet project at a distance of 1,400 feet from the Sheyenne River for any of the six sections.

Based on the results for the six profile models, a plan-view map was developed that depicts the area along the Sheyenne River were the simulations predict that water levels in the aquifer will increase. This map is included in this report as Plate 1.

In simulations of the effects of the Devils Lake Outlet, the water levels near the Sheyenne River were offset (increased) from the baseline condition. However, no carry-over effects are anticipated from year to year because the water levels at the end of the year-long simulation return to the initial levels at the start of the simulation (see Figure F-3.) As described above, it is considered reasonable to assume that the groundwater effects on the north side of the river would be similar to those described for the south side of the river.

5.4.2 Baldhill Pool Raise

The maximum increase in the water table that results from the proposed Baldhill Pool raise is for the 100-year flood event. This maximum increase in the water table as a function of distance from the Sheyenne River is shown on Figure 13 for the six profile sections. The maximum water level increase along all six sections is below 0.1 feet (1.2 inches) within a distance of approximately 750 feet of the Sheyenne River. At approximately 1,500 feet from the Sheyenne River, there is no discernable effect of the Baldhill Pool raise on water levels in the aquifer for the 100-year flood event.

The effects of the 5-year, 10-year, 20-year, and 50-year flood events are less than those for the 100-year flood event and, therefore, are not shown.

Based on the results for the six profile models, a plan-view map was developed that depicts the area along the Sheyenne River were the simulations predict that water levels in the aquifer will increase. This map is included in this report as Plate 2.

5.5 Implications for Water-Quality Effects

Water from the Sheyenne River can only enter the aquifer if the water level in the River is above the water level in the adjacent aquifer materials. As discussed in this report, that condition can only occur during bank-storage conditions. Once the river stage drops, water in bank storage is released back into the river.

The maximum increases in water levels in the aquifer that were predicted from the MODFLOW simulations are not reflective of the degree of incursion of Sheyenne River water. In fact, the distance of maximum incursion is undoubtedly very much closer to the River than the line that represents the maximum extent of water-level increase. This is because a change in water level in the aquifer is not synonymous with a reversal in hydraulic gradient.

As an extremely (and unrealistic) worse-case condition, one can assume that the line of zero water-level increase corresponds to the maximum distance of incursion of Sheyenne River water. Besides the fact that this is hydraulically impossible, other conditions should be considered, such as reactivity of solutes, sorption, aquifer porosity, etc. There are particle tracking and solute-transport models available that could be coupled with MODFLOW to predict the degree of River water excursion into the aquifer, should a better estimate be necessary.

6.0 Conclusions

Based on the review of previous studies and the MODFLOW modeling analysis performed for this study, the following conclusions are presented. Additional details regarding the transient responses are presented in Appendix F.

For the Baldhill Pool Raise

1. The maximum water-level increase in the aquifer, resulting from the Baldhill Pool raise, is predicted to occur during the 100-year flood event. At a distance of approximately 1,500 feet from the edge of the Sheyenne River, the maximum predicted water-level increase is less than 1.2 inches. At a distance of approximately 2,100 feet from the Sheyenne River, there is no effect of the Baldhill Pool raise on water levels.

2. Excursion of Sheyenne River water during the flood event must be less than the maximum extent of water-level effects in the aquifer. Although not specifically modeled as part of this study, it is very likely that the excursion of the river water during the flood event is limited to less than a few tens of feet from the River.

For the Devils Lake Outlet

1. At a distance of approximately 1,500 feet from the edge of the Sheyenne River, the maximum predicted water-level increase is less than 4 inches. At a distance of approximately 2,100 feet from the Sheyenne River, there is no effect of the Devils Lake Outlet on water levels.

2. Excursion of Sheyenne River water during the release of water from the Devils Lake Outlet must be less than the maximum extent of water-level effects in the aquifer. Although not specifically modeled as part of this study, it is very likely that the excursion of the river water during the flood event is limited to less than a few tens of feet from the River.

These conclusions appear to be entirely consistent with observations and analyses made by others during previous studies. The analysis method and selected parameters reflect conditions described in previous studies. For those hydraulic parameters that do not have site-specific values, every attempt was made to use a value that would result in a “worse-case” prediction.

This study indicates that the river-stage increases predicted for the two proposed projects will not cause changes in groundwater levels beyond the immediate vicinity of the Sheyenne River.

Groundwater quality impacts, if any, will be even more restricted the close proximity of the Sheyenne River.

The results of this study indicate that the hydraulic gradients as measured between points beyond the immediate vicinity of the Sheyenne River will be unaffected by the increased flow in the Sheyenne River resulting from the Devils Lake outlet and Baldhill Pool raise (see figures F-7 and F-8). The hydraulic gradient is directly related to flow in a steady-state, one-dimensional flow system. In a three-dimensional, transient flow system such as that in the Sheyenne Delta aquifer, flow is also affected by changes in storage within the aquifer (which tend to dampen the effect of transient pulses in the system), seepage (which removes water from the groundwater system), and evapotranspiration (which also removes water from the groundwater system). In other words, rising groundwater levels in the vicinity of the river do not automatically cause rising groundwater levels in the upland areas. Although the hydraulic gradient between a point in the upland and a point by the river may have been reduced, this does not necessarily cause a rise in groundwater level in the upland area because of increased evapotranspiration, seepage, and placement of water into storage in the aquifer in the areas experiencing rising water level.

The results of this analysis are consistent with preliminary results of a U.S.G.S. study of groundwater/surface interaction in the Sheyenne River Valley. See Appendix G for additional detail.

7.0 References

Anderson, M.A. and W.W. Woesnner, 1992. Applied Groundwater Modeling, Simulation of Flow and Advective Transport, Academic Press, Inc., 381 p.

Armstrong, C.A., 1979. Ground-water basic data for Ransom and Sargent Counties, North Dakota: North Dakota Geological Survey Bulletin 69–Part II and North Dakota State Water Commission County Ground-Water Studies 3–Part II, 637 p.

Armstrong, C.A., 1981. Supplement to: Predictive modeling of effects of the planned Kindred Lake on ground-water levels and discharge, southeastern North Dakota: USGS Open-File Report 81-646, 15 p.

Armstrong, C.A., 1982. Ground-water resources of Ransom and Sargent Counties, North Dakota: North Dakota Geological Survey Bulletin 69–Part III and North Dakota State Water Commission County Ground-Water Studies 31–Part III, 51 p.

Baker, C.H., Jr., 1966. Geology and ground-water resources of Richland County, North Dakota, Part II, Basic data: North Dakota Geol. Survey Bull. 46 and North Dakota State Water Comm. County Ground Water Studies 7, 170 p.

Baker, C.H., Jr., 1967. Geology and ground water resources of Richland County, Part 1, Geology: North Dakota Geological Survey Bulletin 46 and North Dakota State Water Commission County Ground Water Studies 7, 45 p.

Bluemle, J.P., 1979. Geology of Ransom and Sargent Counties, North Dakota: North Dakota Geological Survey Bulletin 69–Part I and North Dakota State Water Commission County Ground-Water Studies 31–Part I, 84 p

Cowdery, T.K. and K. Goff, 1994. Nitrogen concentrations near the water table of the Sheyenne Delta aquifer beneath cropland areas, Ransom and Richland Counties, North Dakota: Proceedings of the North Dakota Water Quality Symposium, Fargo, North Dakota, March 30-31, 1994, North Dakota State University Extension Service, p. 89-102.

Downey, J.S. and Q.F. Paulson, 1974. Predictive modeling of effects of the planned Kindred Lake on ground-water levels and discharge, southeastern North Dakota: USGS Water-Resources Investigations 30-74, 22 p.

Harbaugh, A.W. and M.G. McDonald, 1996. User's Documentation for MODFLOW-96, an update to the U.S. Geological Survey Modular Finite-Difference Ground-Water Flow Model. U.S. Geological Survey Open-file Report 96-485, USGS Branch of Information Services, 56p.

Hopkins, D.G., 1996, Hydrologic and abiotic constraints of soil genesis and natural vegetation patterns in the sandhills of North Dakota: Ph.D. thesis, North Dakota State University.

Lissey, A., 1968. Surficial mapping of ground-water flow systems with application to the Oak River basin, Manitoba: University of Saskatchewan, Ph.D. Thesis, 105 p

McDonald, M.G. and A.W. Harbaugh, 1988. A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model. Techniques of the Water-Resources Investigations of the U.S. Geological Survey, Book 6, Chapter A1. Scientific Software Group, Washington, D.C.

Morris, D.A. and A.I. Johnson, 1967. Summary of hydrologic and physical properties of rock and soil materials as analyzed by the Hydrologic Laboratory of the U.S. Geological Survey 1948-1960, USGS Water Supply Paper 1839-D.

Paulson, Q.F., 1964. Geologic factors affecting discharge of the Sheyenne River in southeastern North Dakota: USGS Professional Paper 501-D, p. D177-181.

Shaver, R., June 9, 1998. North Dakota State Water Commission Office Memo to David Sprynczynatyk, State Engineer, through Milton O. Lindvig, Director, Water Appropriations Division–Conditional Water Permit Application #5188, 31 p.

Sieg, C.H. and P.M. Wolken, 1998. Dynamics of a threatened orchid in flooded wetlands (DRAFT): submitted to 16th North Am. Prairie Conference, July 26-29, 1998, Kearny, NE, 21 p.

Strobel, M.L. and S.A. Radig, 1997. Effects of the 1993 flood on water levels and water quality in the Sheyenne Delta aquifer, southeastern North Dakota, 1993-94. USGS Water-Resources Inv. Report 97-4163, 43 p.

Walton, W.C., 1970. *Groundwater Resource Evaluation*: McGraw-Hill Book Co., New York, NY, 664 p.

Table 1

Estimated Aquifer Parameters and Water Budget Elements

Parameter	**Estimated Value**	**Source and Comments**
Water Budget Factors		
Annual recharge to the Sheyenne Delta aquifer	50,000 acre-feet/year (assuming area of 300 mi^2,)	Baker and Paulson, 1967, p. 25
	6 in/year to 8 in/year	Armstrong, 1982, p. 33; based on a digital model of part of the delta area
Portion of recharge discharged to the Sheyenne River	1 in/year to 3 in/year of the total 6 in/year to 8 in/year	
Portion of recharge discharged to evapotranspiration	5 in/year of the total 6 in/year to 8 in/year	
Groundwater discharge from the Sheyenne Delta aquifer to the Sheyenne River	91.6 ft3/sec in May, 1972	Downey and Paulson, 1974, p. 12; lower value measured in August attributed to evaporation from the stream
Groundwater discharge from the Sheyenne Delta aquifer to the Sheyenne River	0.16 ft3/sec per mile of river during October through February for the period 1957-1962	Paulson, 1964, Table 1; use this value in profile model calibration
Total pumpage from the Sheyenne Delta aquifer in Ransom and Sargent Counties	830 acre-feet in 1977	Armstrong, 1982, p. 33
Total pumpage from the Sheyenne Delta aquifer in eastern Ransom County	2000 acre-feet in 1996, applied over 2500 acres	Shaver, 1998, Figure 12
Average irrigation application rate on the Sheyenne Delta aquifer in eastern Ransom County	9.7 inches/acre	Shaver, 1998, p. 10
Total approved appropriation from the Sheyenne Delta aquifer	19,120 acre-feet	Shaver, 1998, p. 13
Potential (maximum) evaporation rate	30 in/year	Meyers, 1962 in Downey and Paulson, 1974, p.15
Annual precipitation	497 mm (19.57 in/yr)	Sieg and Wolken, 1998
Depth of maximum evapotranspiration surface	7.16 feet	Downey and Paulson, 1974, p. 16
Extinction depth for evapotranspiration	8 feet below ground surface	Inferred from discussion on pp. 3-4 of Shaver, 1998
	3.8 feet below the maximum evapotranspiration surface for silty clay; 7 feet below the maximum evapotranspiration surface for silty sand	Downey and Paulson, 1974, p. 16

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Table 1 (cont.)

Estimated Aquifer Parameters and Water Budget Elements

Aquifer Parameters		
Transmissivity of the Sheyenne Delta aquifer	700 ft2/day, 850 ft2/day, 1000 ft2/day	Downey and Paulson, 1974, p. 8; based on aquifer testing
	6000 ft2/day (saturated thickness 33 feet, K = 180 ft/day)	Shaver, 1998, Table 1; values for tests of 100 hour duration; wells located near western margin of aquifer (coarsest material)
Hydraulic conductivity of various lithologies of the Sheyenne Delta aquifer:		Downey and Paulson, 1974, p. 9; based on laboratory testing
Silty clay	1e-4 ft/day	
Clay, silt, and sand	1e-3 ft/day	
Clayey silt	3e-2 ft/day	
Silt	3e-1 ft/day	
Silty sand	1.1 ft/day	
Very fine to fine sand	7.2 ft/day	
Fine sand	16.5 ft/day	
Fine to medium sand	30 ft/day	Downey and Paulson, 1974, p. 9; based on grain size distribution
Medium sand	60 ft/day	
Transmissivity of the sand facies of the Sheyenne Delta aquifer	1400 ft2/day	Downey and Paulson, 1974, p. 9
Transmissivity of the silt-clay facies of the Sheyenne Delta aquifer	200 ft2/day	Downey and Paulson, 1974, p. 9
Hydraulic conductivity distribution for the Sheyenne Delta aquifer	variable	Downey and Paulson, 1974, plate 3
Specific yield of the Sheyenne Delta aquifer	0.2	Downey and Paulson, 1974, p. 14 (used in model, source not indicated)
Specific yield of the coarser units of the Sheyenne Delta aquifer	0.17	Baker and Paulson, 1967, p. 21 based on comparison of lithology to that in which an aquifer test was performed in the Hankinson aquifer (Powell, 1956, p. 20)
Specific yield of soils similar to those developed on the Sheyenne Delta aquifer	0.25	Shaver, 1998, p. 8; based on laboratory and field testing

Table 2A

Average Discharges and River Stages at the Lisbon and Kindred Gages (Baseline Conditions)

Month	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sep.**
Gage	Lisbon											
Discharge (cfs)	66.5	77.6	74.2	68.8	86.3	334	795	357	174	170	109	68.5
Stage (ft. above datum)	2.46	2.54	2.50	2.47	2.59	3.97	6.01	4.09	3.14	3.12	2.74	2.46
Elevation (m MSL)	1068.92	1069.00	1068.96	1068.93	1069.05	1070.43	1072.47	1070.55	1069.60	1069.58	1069.20	1068.92
Elevation (m MSL)	325.890	325.915	325.902	325.893	325.930	326.351	326.973	326.387	326.098	326.091	325.976	325.890
Gage	Kindred											
Discharge (cfs)	86.9	95.9	84.8	75.8	88	309	834	515	274	238	141	87.3
Stage (ft. above MSL)	2.58	2.63	2.57	2.53	2.59	3.75	6.84	4.91	3.58	3.38	2.86	2.59
Elevation (ft. MSL)	928.13	928.18	928.12	928.08	928.14	929.3	932.39	930.46	929.13	928.93	928.41	928.14
Elevation (m MSL)	282.966	282.982	282.963	282.951	282.970	283.323	284.265	283.677	283.271	283.210	283.052	282.970

Table 2B

Assumed Discharges and River Stages at the Lisbon and Kindred Gages, Including Discharge from the Devils Lake Outlet

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Gage	Lisbon	River Mile	162.1									
Discharge (cfs)	68.8	86.3	334	795	657	474	470	409	368.5	366.5	377.6	74.2
Stage (ft above datum)	2.47	2.59	3.97	6.01	5.45	4.65	4.63	4.35	4.14	4.13	4.19	2.50
Elevation (ft MSL)	1068.93	1069.05	1070.43	1072.47	1071.91	1071.11	1071.09	1070.81	1070.60	1070.59	1070.65	1068.96
Elevation (m MSL)	325.893	325.930	326.351	326.973	326.802	326.558	326.552	326.466	326.402	326.399	326.418	325.902
Gage	Kindred	River Mile	67.9									
Discharge (cfs)	75.8	88	309	834	815	574	538	441	387.3	386.9	395.9	84.8
Stage (ft above datum)	2.53	2.59	3.75	6.84	6.72	5.26	5.04	4.48	4.17	4.17	4.22	2.57
Elevation (ft MSL)	928.08	928.14	929.3	932.39	932.27	930.81	930.59	930.03	929.72	929.72	929.77	928.12
Elevation (m MSL)	282.951	282.970	283.323	284.265	284.229	283.784	283.716	283.546	283.451	283.451	283.466	282.963

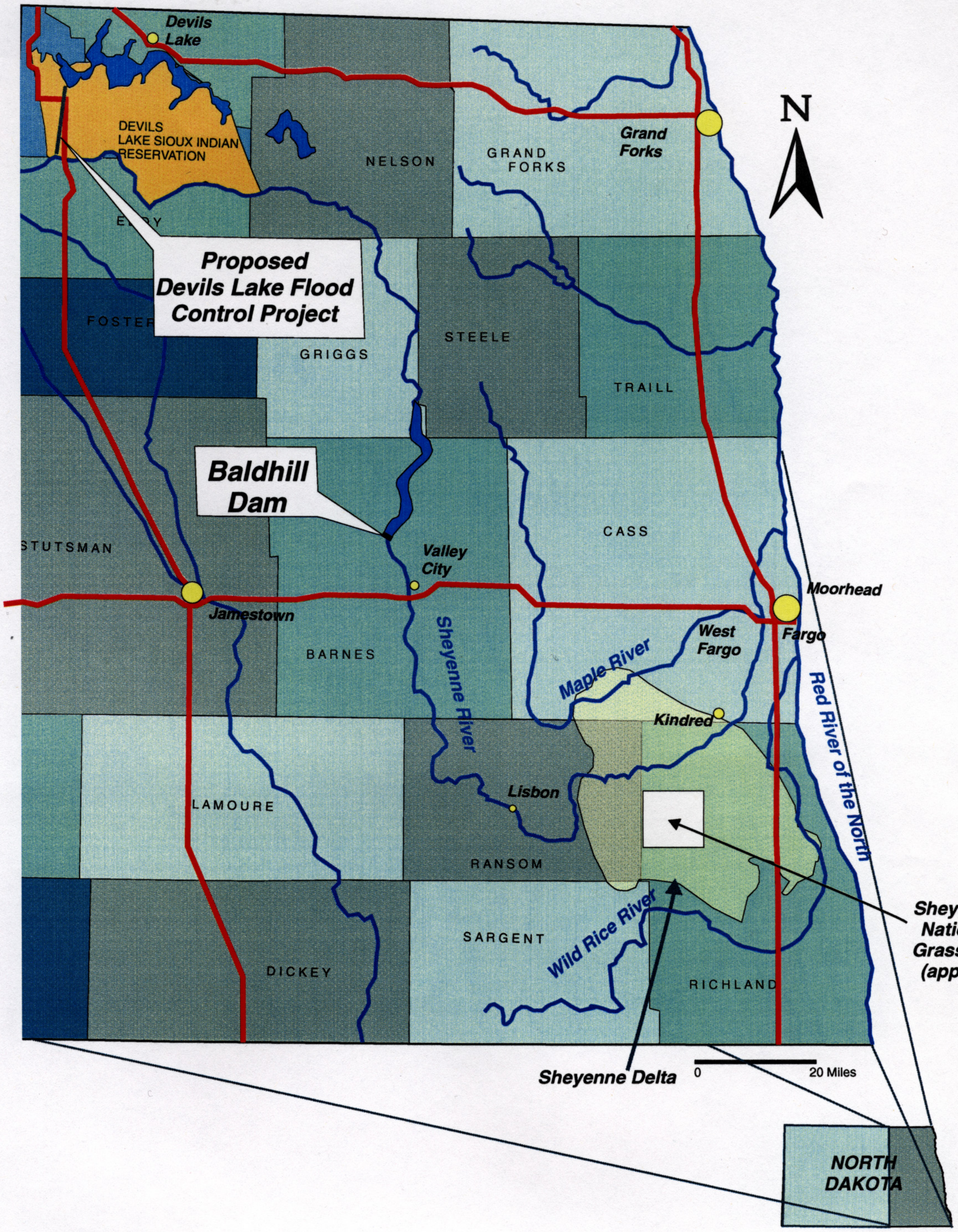
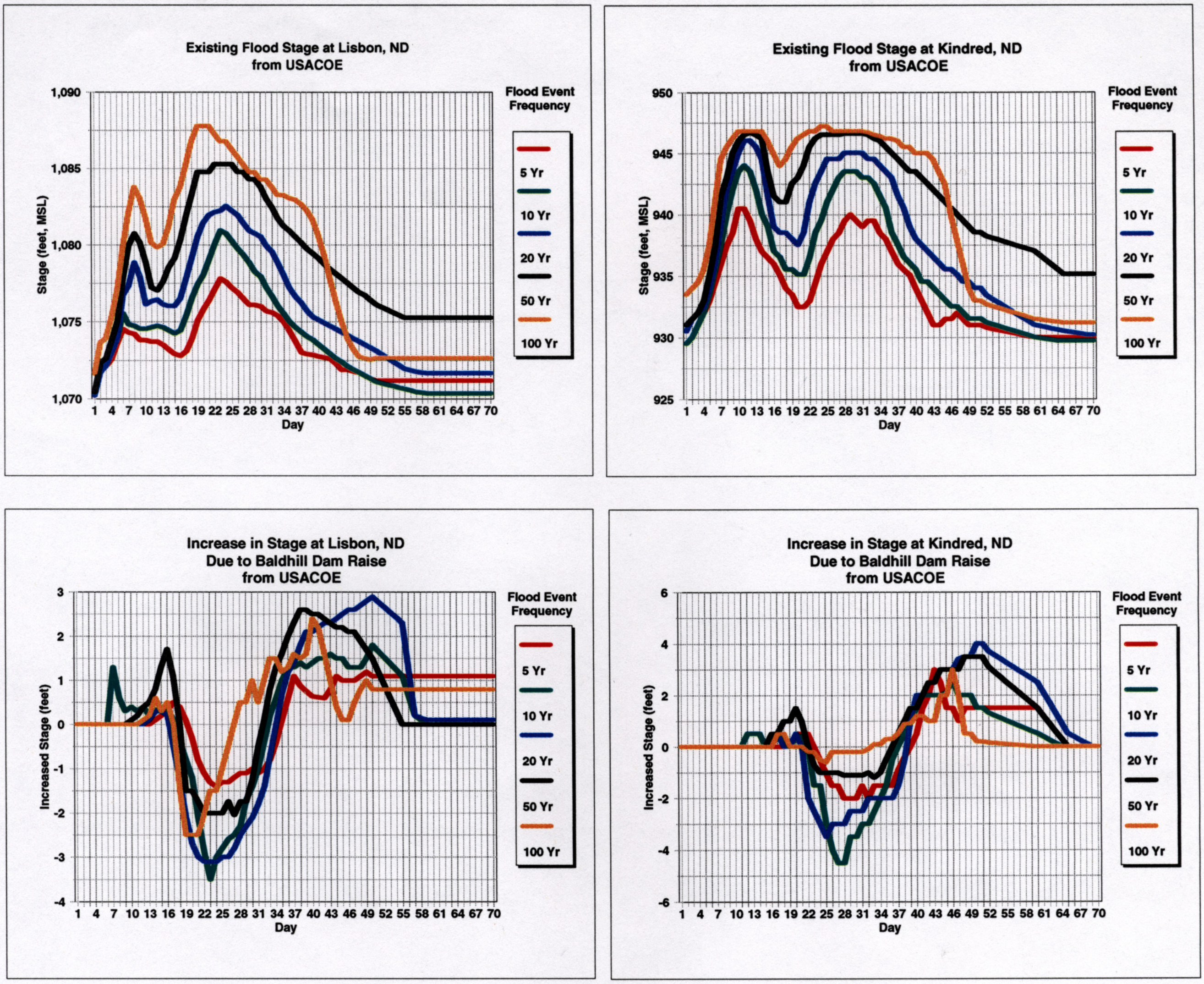


Figure 1

LOCATION OF STUDY AREA



Data from US Army Corp of Engineers - St. Paul District

Figure 2

PREDICTED EFFECTS OF BALDHILL DAM ON STAGE ELEVATION OF SHEYENNE RIVER AT LISBON AND KINDRED, NORTH DAKOTA

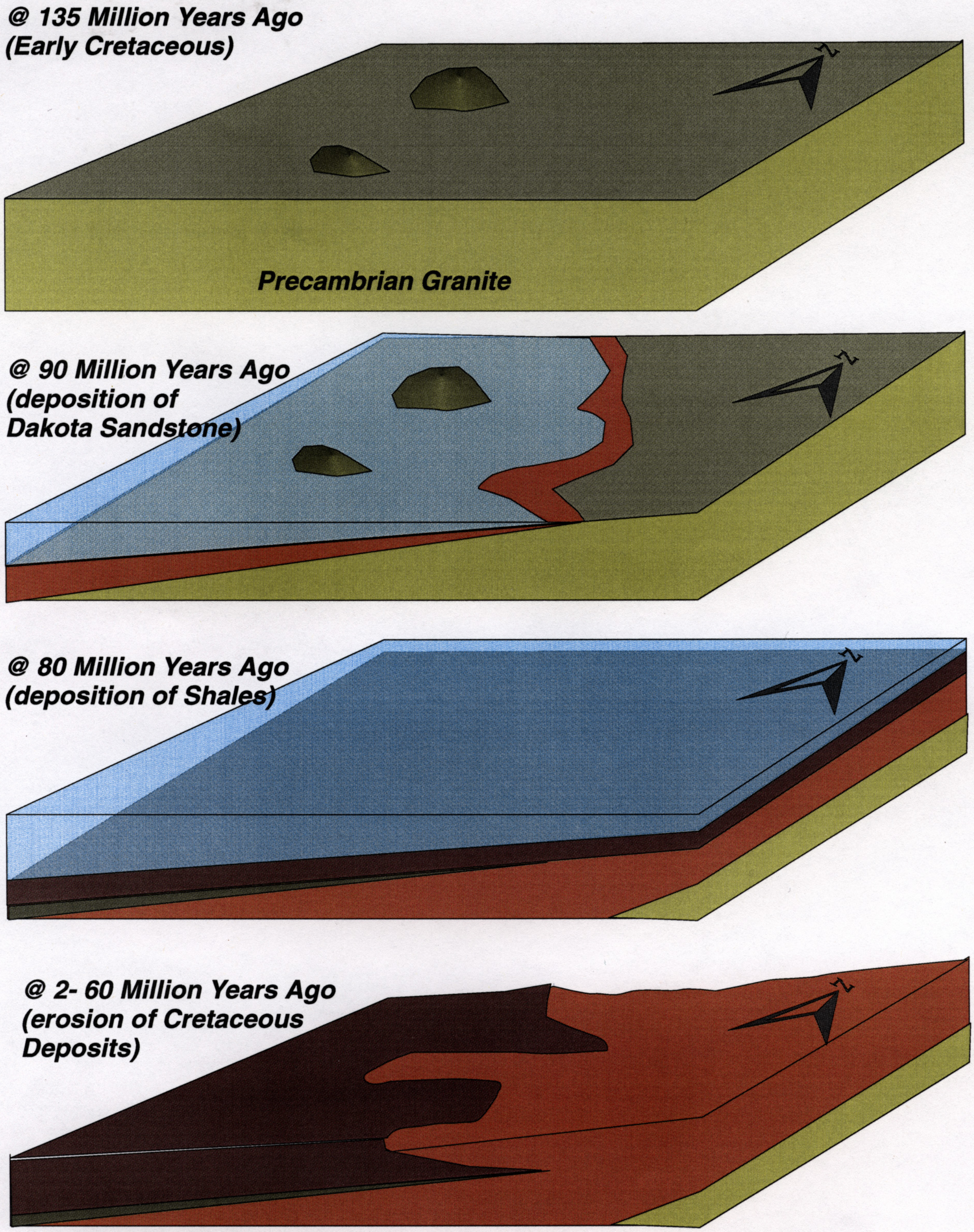


Figure 3

PRE-PLEISTOCENE GEOLOGIC HISTORY

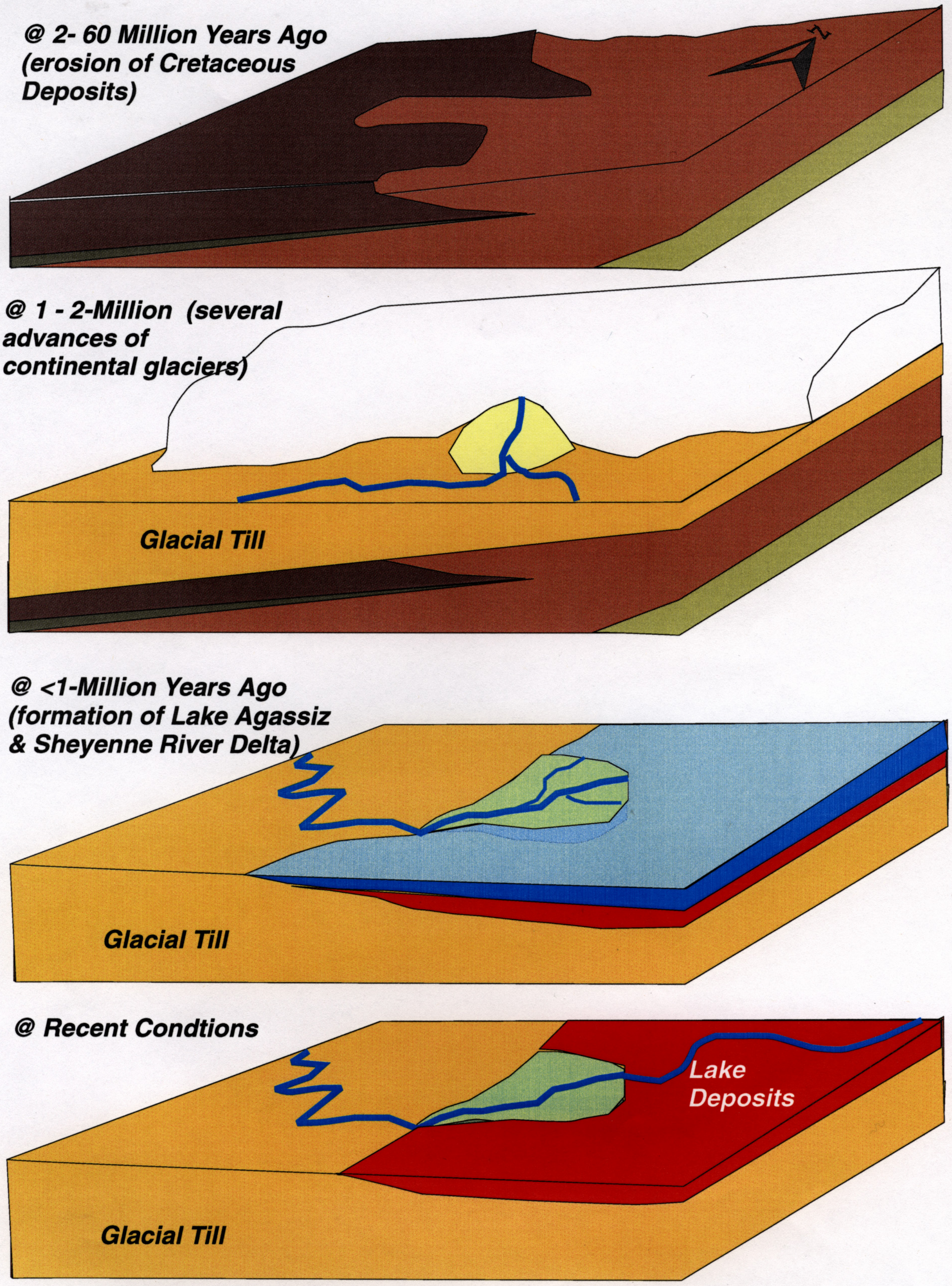


Figure 4

PLEISTOCENE GEOLOGIC HISTORY

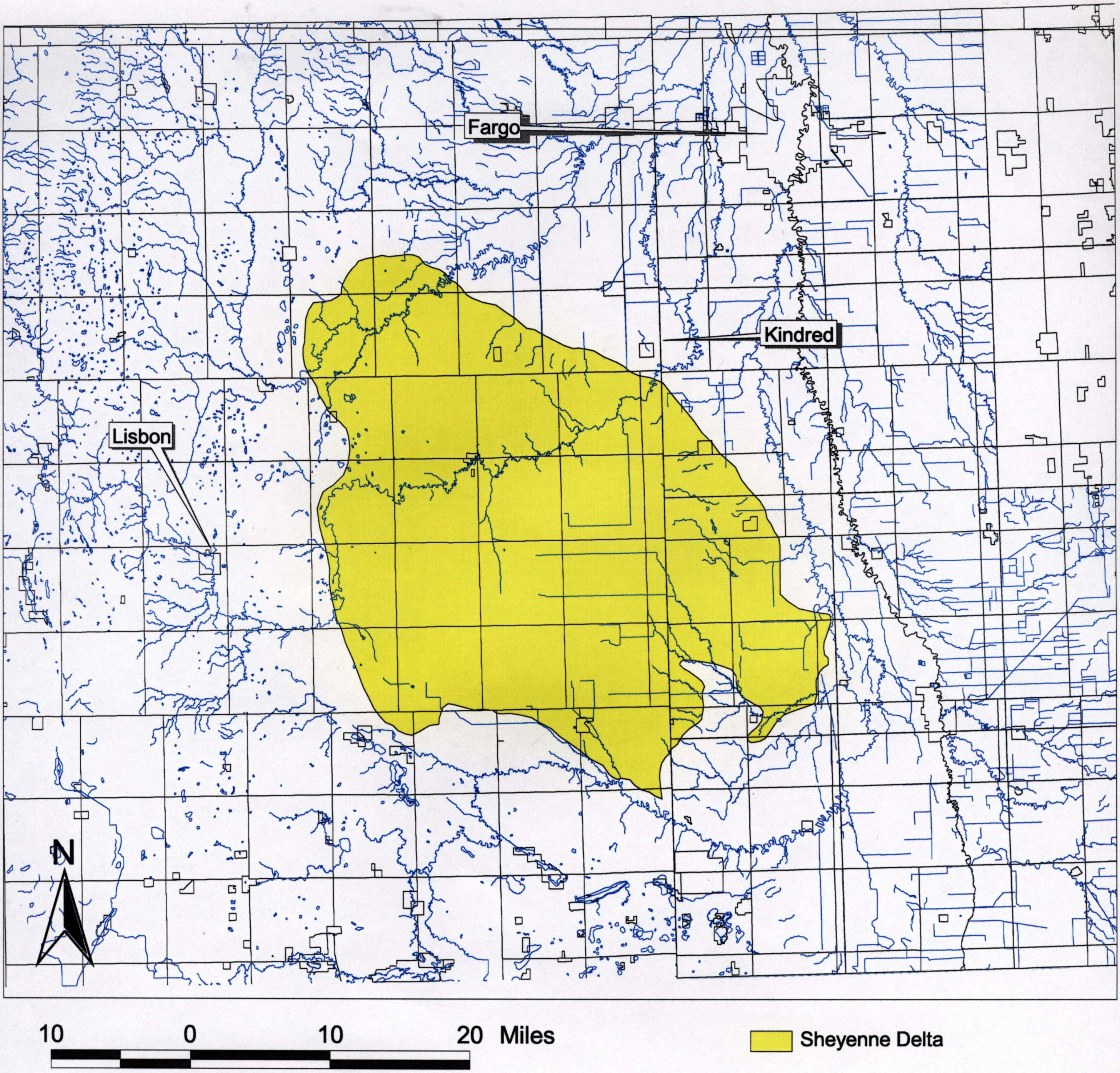


Figure 5

AREAL EXTENT OF THE SHEYENNE DELTA

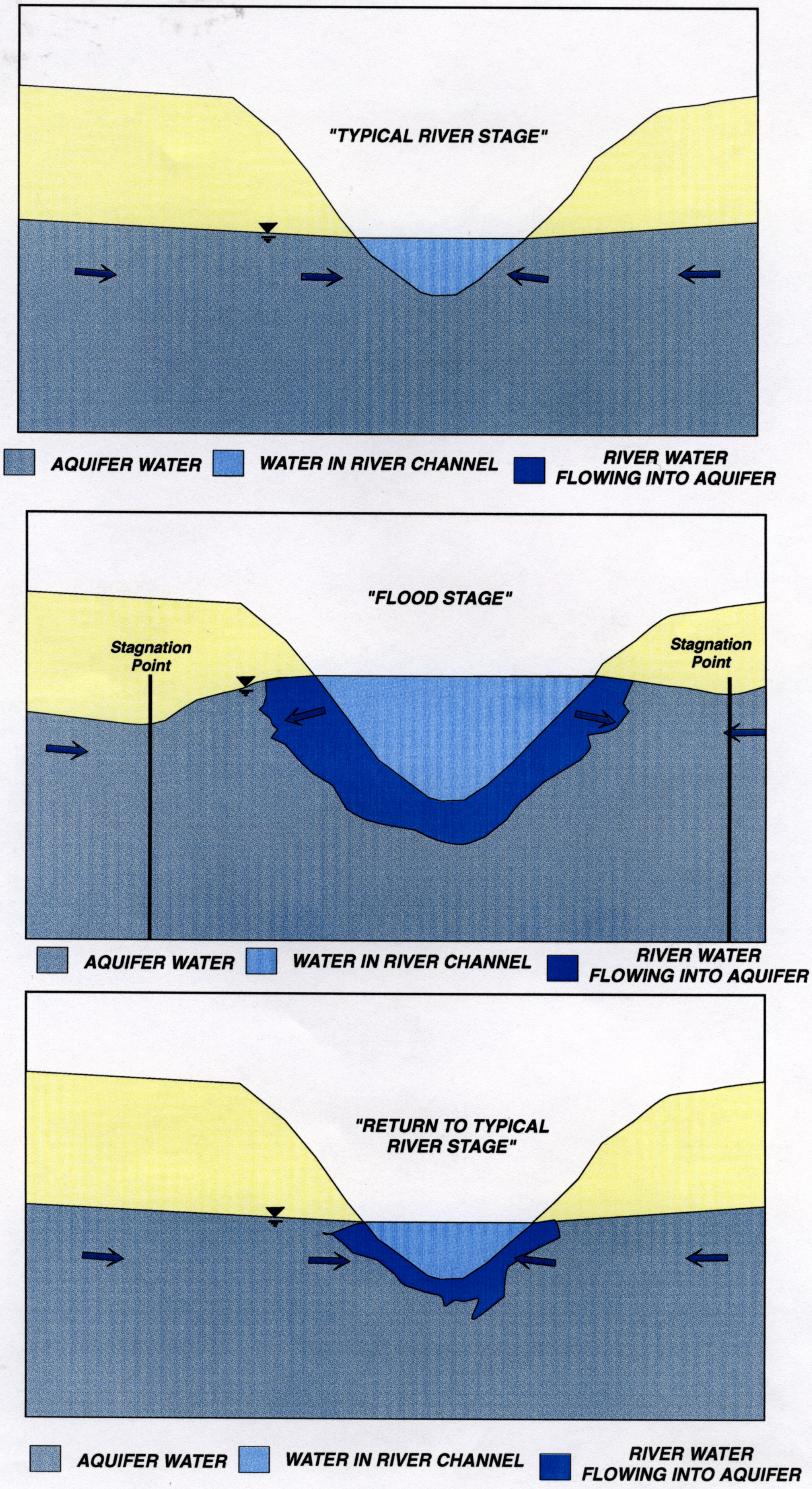
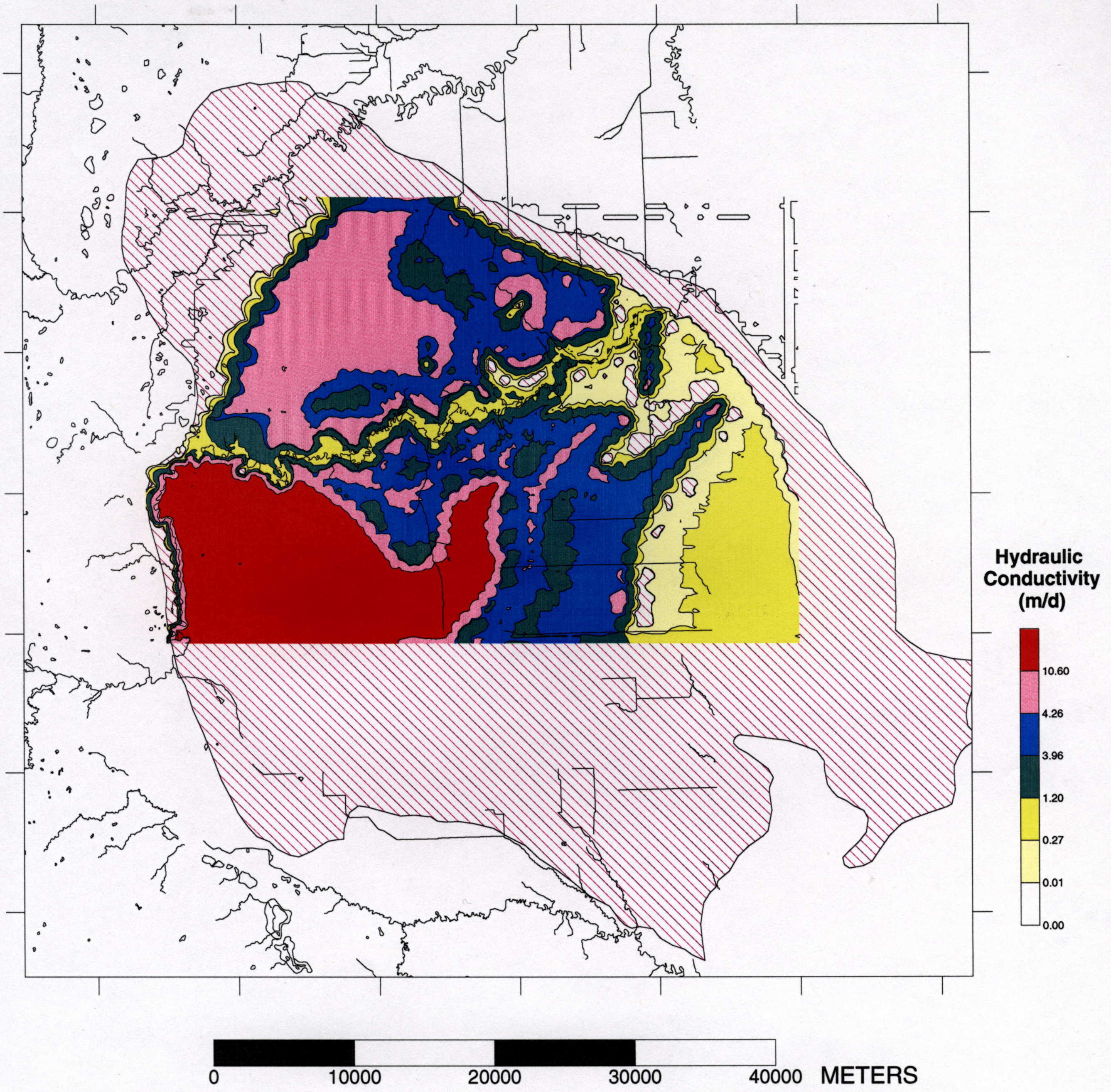


Figure 6

SCHEMATIC ILLUSTRATION OF BANK STORAGE

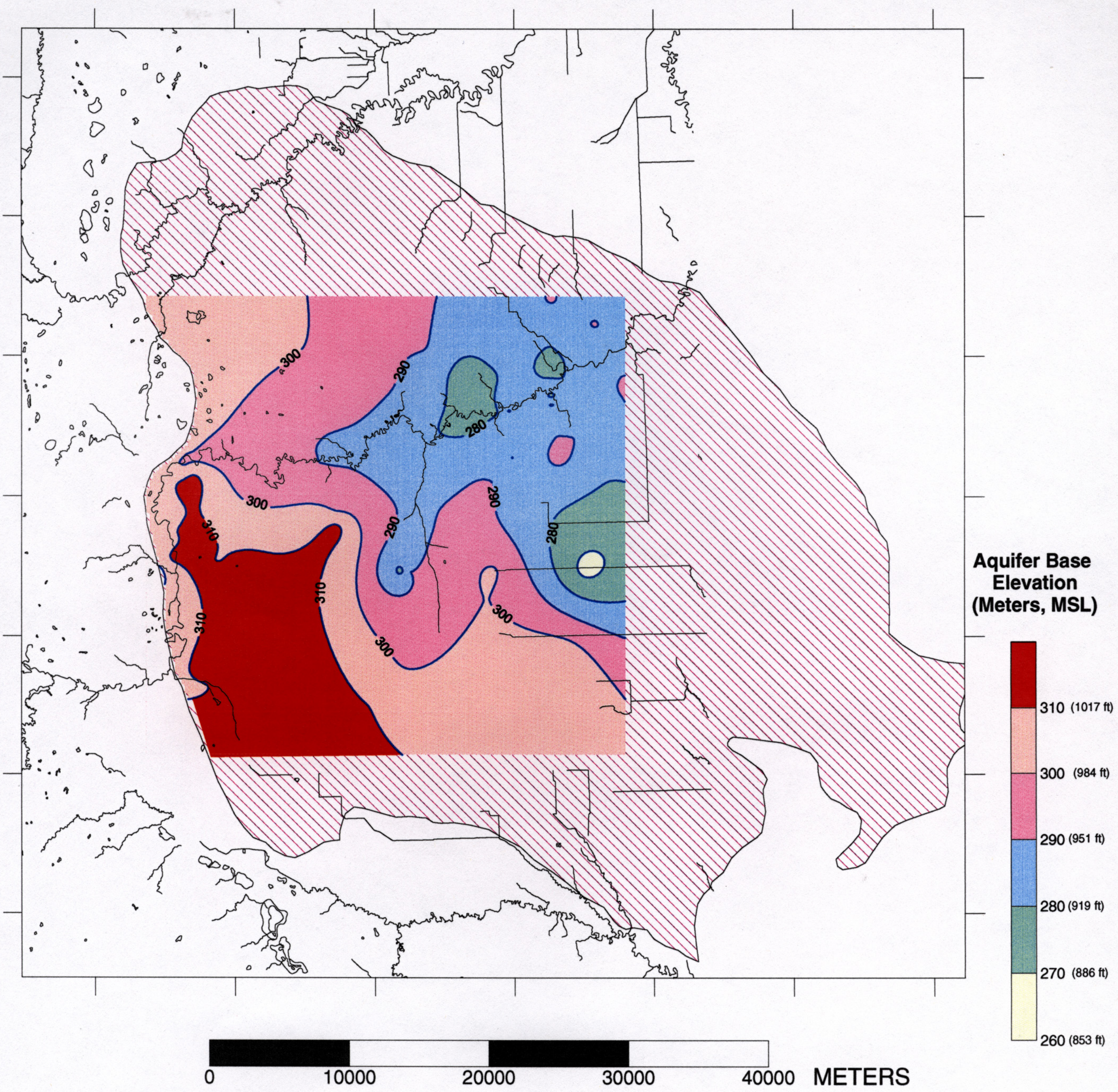


Kriged surface, digitized from
Downey and Paulson (1974)

Portion of Sheyenne Delta Aquifer
not Characterized by Downey and Paulson (1974)

Figure 7

HYDRAULIC CONDUCTIVITY DISTRIBUTION OVER
THE PORTION OF THE SHEYENNE DELTA AQUIFER
NEAR THE SHEYENNE RIVER (after Downey and Paulson, 1974)



Kriged surface, digitized from Downey and Paulson (1974), Baker (1967), and Armstrong (1979)

Portion of Sheyenne Delta Aquifer not Characterized by Base Elevation Data

Figure 8

BASE ELEVATION (METERS, MSL) OVER THE PORTION OF THE SHEYENNE DELTA AQUIFER NEAR THE SHEYENNE RIVER

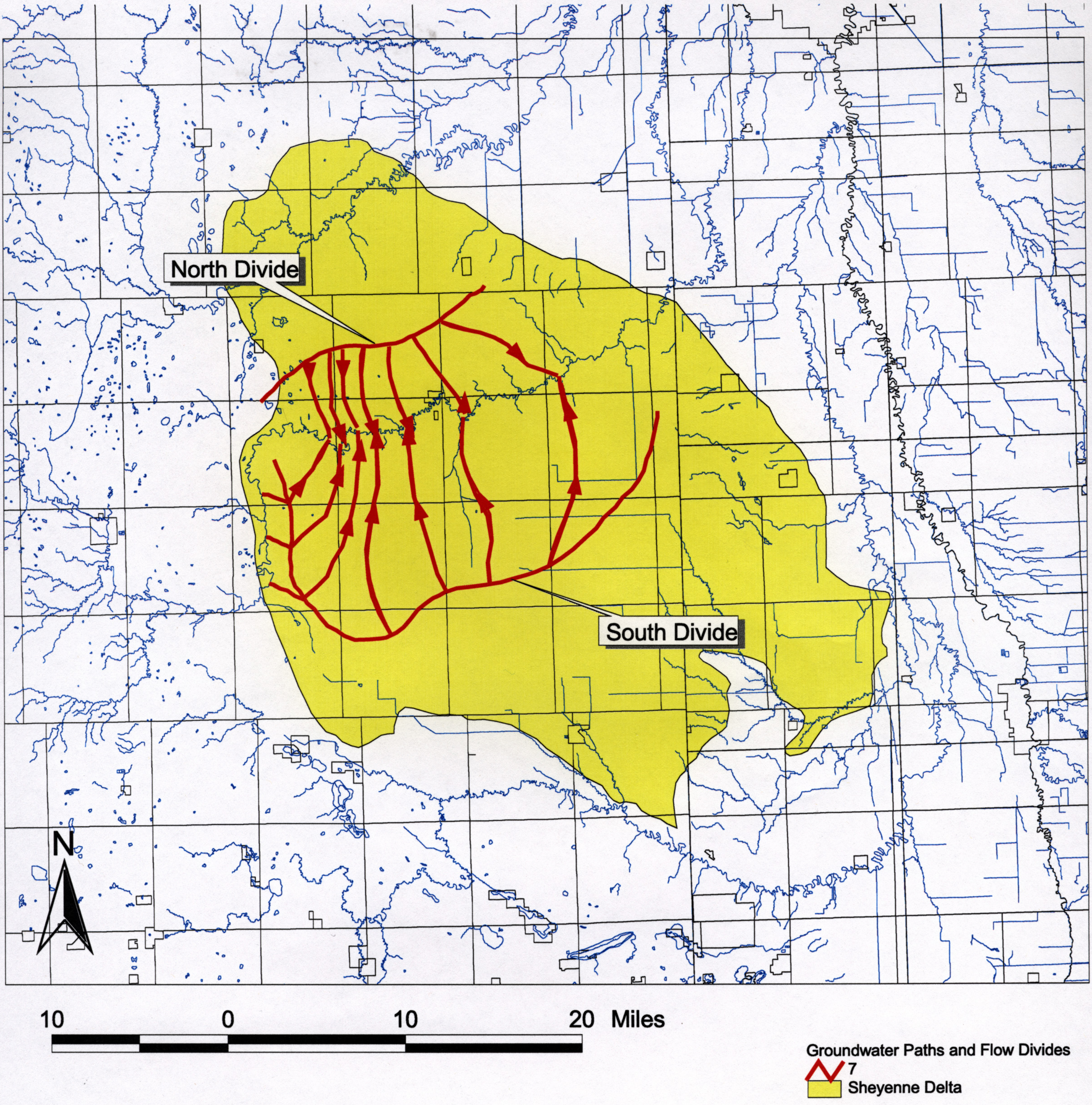


Figure 9

INFERRED GROUNDWATER FLOW DIVIDES AND
GROUNDWATER FLOW PATHS
(after Paulson, 1964)

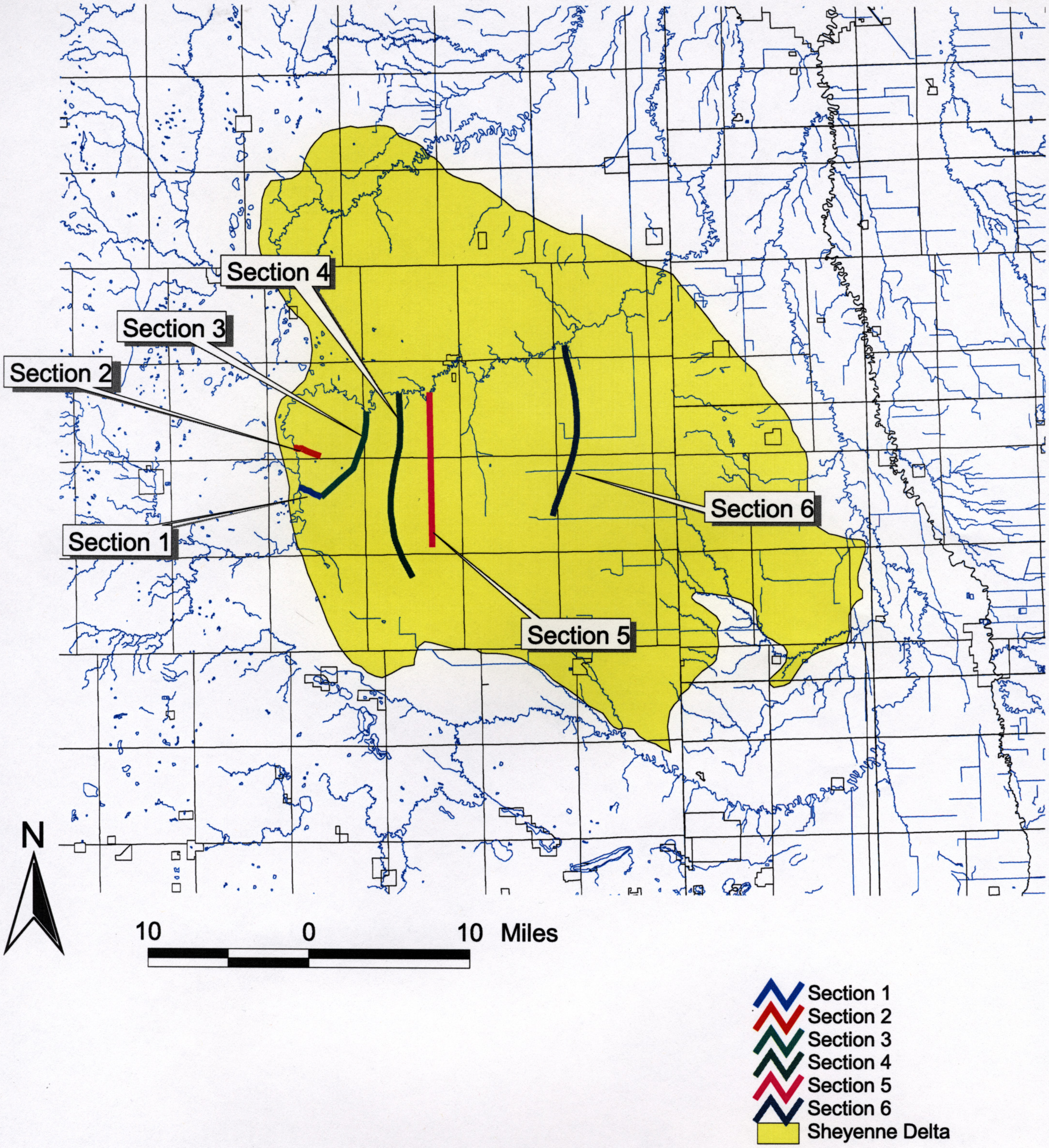


Figure 10

SECTION LOCATIONS FOR PROFILE MODELING

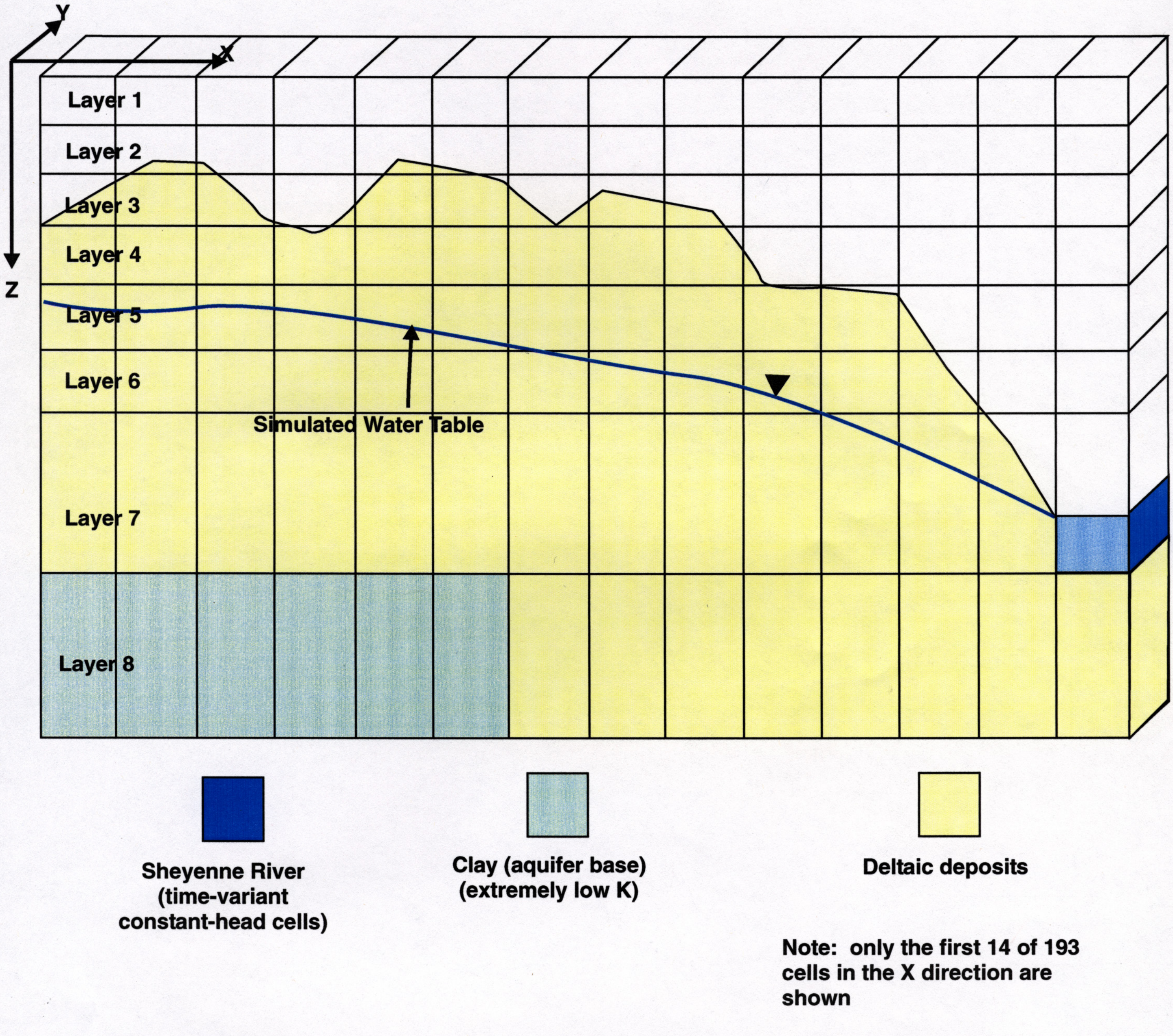


Figure 11

EXAMPLE OF MODFLOW PROFILE MODEL
USED IN THIS STUDY

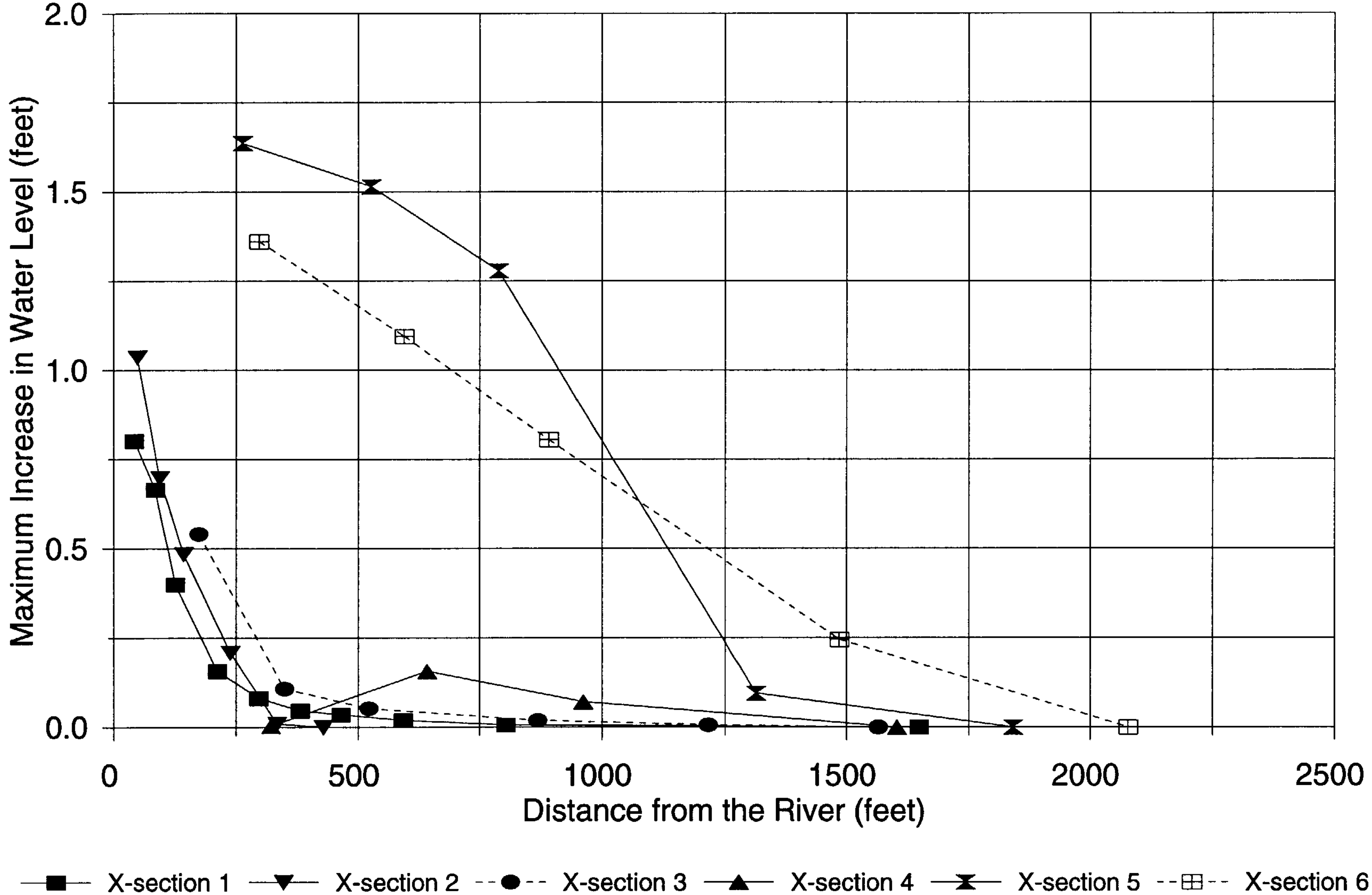


Figure 12
Maximum Simulated Effects of the Devils Lake Outlet

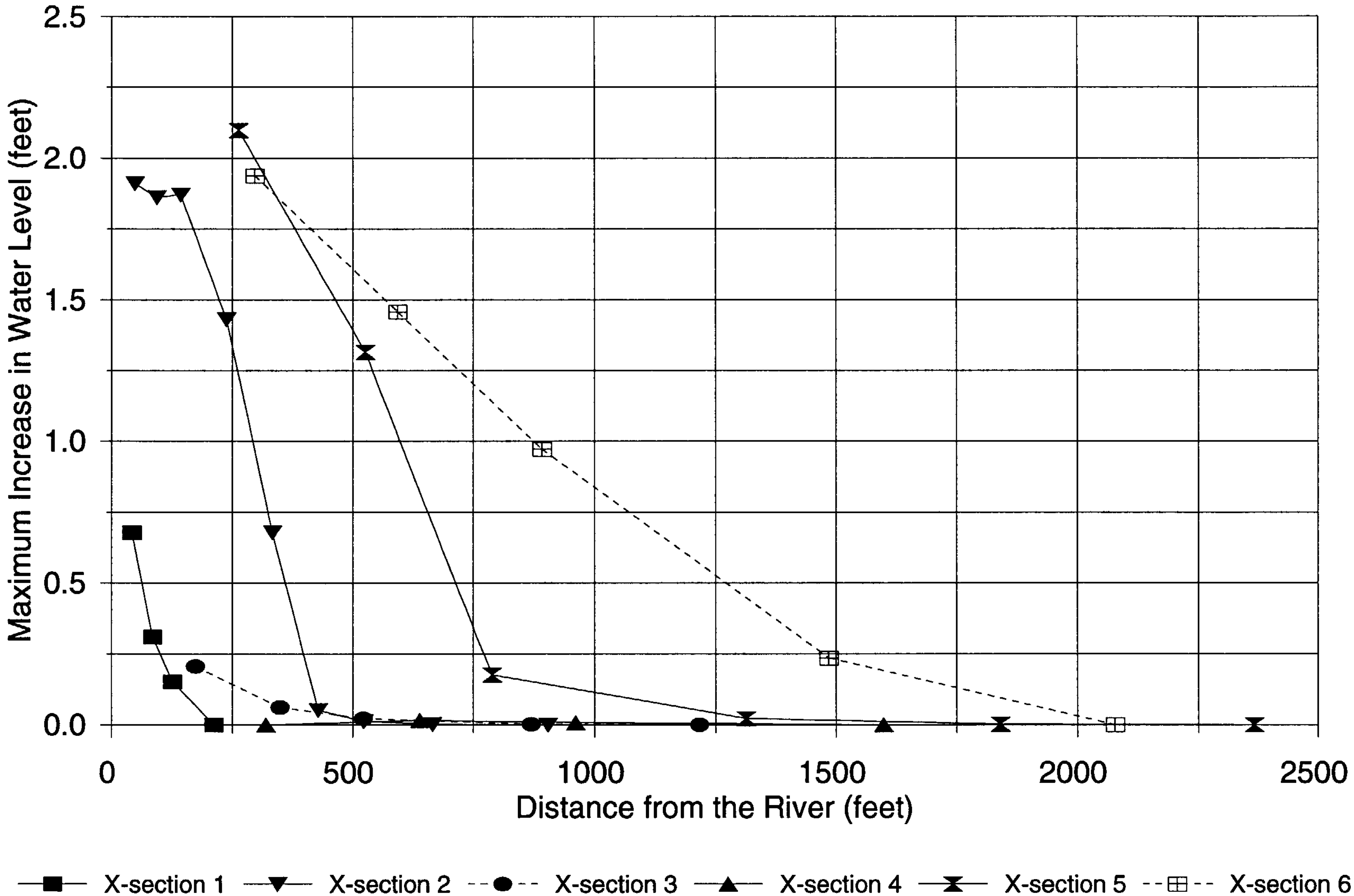


Figure 13
Maximum Simulated Effects of the Baldhill Dam Pool Raise

Appendices

Appendix A

Annotated Bibliography

Strobel, M.L. and S.A. Radig, 1997. Effects of the 1993 flood on water levels and water quality in the Sheyenne Delta aquifer, southeastern North Dakota, 1993-94. USGS Water-Resources Inv. Report 97-4163, 43 p.

Summary

A study was conducted to evaluate the effects of precipitation and flooding on water levels in the Sheyenne Delta aquifer and to evaluate the variations in water quality that are related to the precipitation and flooding. Water-level, streamflow, and water-quality data collected prior to July 1993 were assumed in this study to be representative of pre-flood conditions. Data collected from July 1993 through May 1994 were used to evaluate the groundwater response.

Water levels in 49 wells were measured every three weeks between November 1993 and May 1994. Water samples were collected from 16 wells during November 1993 and March, April, and May 1994 and were analyzed for major ions, nutrients, selected trace elements (arsenic and selenium) and pesticides. The water-level and water-quality data collected during the study, along with similar data collected during the NWQA study provided the basis for describing the general characteristics of the hydrology and water quality of the Sheyenne Delta aquifer.

The study area is a deltatic deposit formed along the margins of glacial Lake Agassiz during the Pleistocene. The Sheyenne Delta aquifer drains to the Sheyenne River. The aquifer underlies parts of Cass, Ransom, and Richland Counties and part of the Sheyenne River Valley and adjacent areas between the cities of Lisbon and Kindred. Land overlying the aquifer consists of about 440 square miles of relatively flat lake plain and gently rolling hills, referred to as low-relief areas in this study. The steep banks and hills are adjacent to the river (high-relief areas) and were produced by surface erosion and eolian dune formation. The land overlying the aquifer is used mainly for cattle grazing and corn and soybean production. Surface drainages (other than the Sheyenne River) are poorly developed because of permeable soils and deltaic deposits. Groundwater flow is generally toward the river or to the east. Discharge from the aquifer is mainly to the Sheyenne River, to springs along the northeast edge of the delta, and (to a lesser extent) to wells and by evapotranspiration.

Streamflow measurements on the Sheyenne River between Valley City and West Fargo (Paulson, 1964; Harkness et al., 1988) indicate that discharge from the Sheyenne Delta aquifer provides substantial baseflow to the Sheyenne River. Measurements made during September through November 1963 showed an increase in streamflow of about 29 cfs between Lisbon and Kindred with no tributary flows (indicates that @ 75% of streamflow at Kindred was from discharge from Sheyenne Delta aquifer (Paulson, 1964)). Measurements made during October 1986 showed an increase of about 52 cfs between Lisbon and Kindred with no tributary inflows (@ 68% of streamflow at Kindred was from aquifer (Harkness et al., 1988)). Difference in two sets of measurements indicates greater release from the Baldhill Dam upstream from Valley City and a wetter climate pattern during 1986 than during 1963. During the wetter period, more

water was discharged from the Sheyenne Delta aquifer to the Sheyenne River but the difference in the ratio of groundwater discharge to total streamflow for the two periods was only 7 percent.

Summary of Geology

The Sheyenne Delta, which generally delineates the Sheyenne Delta aquifer is a Pleistocene, near-surface feature that overlies lacustrine sediments of glacial Lake Agassiz (Baker, 1967a). The delta consists mainly of interbedded fine to medium sand and silt that generally is 49 to 140 feet thick (Downey and Paulson, 1974). The delta is bounded by glacial drift on the west and south and grades into lacustrine sediments in the east and north. The deltaic deposits grade from predominantly sand in the southwest to predominantly silt and clay in the northeast (Downey and Paulson, 1974). The northeastern edge of the delta forms an escarpment and is continuous with sandy deposits of the Campbell beach, one of the lower shorelines of glacial Lake Agassiz (Baker, 1967a). Grain size in the deltaic deposits generally increases in both the upward and shoreward (southwest) directions because of the progradation of the delta into glacial Lake Agassiz (Cowdery and Goff, 1994). In many places, the deltaic deposits have been modified into sand dunes by wind action (Downey and Paulson, 1974).

The low-relief areas of the Sheyenne Delta consist of Ulen-Hecla association soils and, to a lesser degree, Ulen-Stirum association soils (Omodt et al., 1968). In both types of soils, surface drainage is absent and precipitation and snowmelt percolate to the water table. Permeability is moderately high and infiltration is moderately rapid. The high-relief areas of the Sheyenne Delta consists of Valentine-Hecla-Hamar association soils (Omodt et al. 1968). Surface drainage in these soils also is absent and precipitation and snowmelt percolate rapidly to the water table. Permeability is high, infiltration is rapid, and the water-retention capacity is small (Omodt and others, 1968).

Pleistocene lacustrine clays about 100 feet thick underlie the Sheyenne Delta aquifer throughout the study area (Downey and Paulson, 1974). The clays, which are plastic and have low hydraulic conductivity, form a relatively impermeable basal unit to the aquifer. The contact between the aquifer and the lacustrine clays is poorly defined because the prograding delta deposits over its own bottomset beds, which have essentially the same composition as the lacustrine clays (Baker, 1967a).

A thick sequence of Pleistocene-age till and stratified drift underlies the lacustrine clays (Downey and Paulson, 1974). The 81- to 263-foot thick sequence of glacial deposits has low hydraulic conductivity and, along with the lacustrine clays, generally isolates the Sheyenne Delta aquifer from any significant hydrologic interaction with bedrock aquifers. The major water-bearing bedrock unit underlying the Sheyenne Delta aquifer is sandstone in the Cretaceous Dakota Group.

Hydraulic conductivity in the Sheyenne Delta aquifer decreases from the southwest to the northeast (Downey and Paulson, 1974). This trend is consistent with the grain-size distribution expected in a delta that was formed from a river discharging into glacial Lake Agassiz from the southwest. Downey and Paulson (1974) conducted aquifer tests at 3 locations on the delta, measured hydraulic conductivity in 25 core samples, and applied the water-table profile-analysis method (Rorabaugh, 1960) at various locations to produce a map of hydraulic conductivities for the aquifer. Transmissivities range from about 200 feet squared per day in the silt/clay facies to about 1,400 feet squared per day in the sand facies (Downey and Paulson, 1974).

The Sheyenne Delta aquifer is unconfined throughout the study area and is recharged by direct infiltration of snowmelt and rain. Except for the Sheyenne River, surface drainage across the aquifer is minor because of the generally rapid infiltration of snowmelt and rain through the sandy soils into the aquifer. During the study (July 1993 through May 1994), the water level in low-relief areas ranged from above land surface (surface ponding) to 20.5 feet below land surface. The water level in high-relief areas ranged from 3.5 to 24.1 feet below land surface, commonly about twice as deep as in low-relief areas.

The hydraulic findings of this study are as follows:

- precipitation and flooding affect water levels in the aquifer
- the largest water level rises in the aquifer are associated with low-relief areas, where rapid infiltration of snowmelt, runoff, and precipitation can take place.
- topography strongly affects the focus of recharge in the aquifer. Snowmelt and precipitation infiltrate into the aquifer in low-relief areas during early spring and produced a rise in water levels. Snowmelt and precipitation in high-relief areas, typically in areas near the river, either travel as surface runoff to low-relief areas or to the river or infiltrate to the water table and flow in the direction of the steep hydraulic gradient toward the river.
- the water table elevations change little during frozen winter months
- delayed recharge may be taking place in areas with thicker unsaturated deposits, due to delayed recharge percolation to the water table.
- during March, water levels in the aquifer rose by more than 2 feet in some areas as substantial recharge took place over large parts of the aquifer, in response to precipitation and snow melt. Water levels then generally declined during the first half of April as snow melt declined.
- Excessive precipitation in late April produced higher water levels throughout the aquifer. The streamflow peak resulting from the late April rains occurred quickly than the normal post-snowmelt streamflow recession continued.
- regional flow is from upland areas to the river, at both high and low flood/recharge conditions. Steepest hydraulic gradients are near the river.
- reversals of groundwater flow very near the river were inferred from water-level data during high stage conditions in the river (i.e. bank storage). These reversals were "temporary" (less than one month) in duration and very localized near the river (less than one mile from river). Overall hydraulic gradients to the river decreased slightly during this period, due both to higher river stage and to increased infiltration over the aquifer.

- Authors estimate that high stage levels on the Sheyenne River in July and August 1993 probably caused water-table gradients near the river to reverse and water from the river flowed into the aquifer as temporary bank storage. "Direct effects of the 1993 flood on water levels in the aquifer probably were limited to the area adjacent to the river." "However, excessive precipitation associated with the flood probably affected water levels throughout the aquifer. Water levels in two observation wells in the aquifer indicate that the water table generally was about 2 feet higher during the fall and winter of 1994 than during the fall and winter of 1993." (P. 35).

The water-quality findings of this study are as follows:

- The aquifer is generally a calcium bicarbonate or calcium magnesium bicarbonate type, with dissolved-solids concentrations ranging from 269 to 1,820 mg/L.
- "No discernable differences existed between the pre-flood data and the post flood data for both dissolved-solids and chloride concentrations." (P. 35)
- where major-ion concentrations did change, the change was probably the result of a combination of interaction between the aquifer and the Sheyenne River and recharge from snowmelt.
- Nitrite plus nitrate concentrations were generally less than 1.0 mg/L as N and no spatial or temporal pattern was apparent.
- Phosphate concentrations ranged from 0.03 to 1.9 mg/L as P and orthophosphate concentrations ranged from less than 0.01 to 0.32 mg/L as P. The largest concentrations of both constituents was in well SF-1S, located adjacent to the Sheyenne River.
- large arsenic and selenium concentrations were measured in some samples from the Sheyenne Delta aquifer. Arsenic concentrations ranged from less than 1 to 110 ug/L ad a sample from well SD-22 exceeded the State standard of 50 ug/L. Selenium concentrations ranged from less than 1 to 53 ug/L and one sample from well SD-26 exceeded the State standard of 50 ug/L. Generally arsenic and selenium concentrations were inversely proportional.
- The only pesticide detected was picloram and it was randomly distributed (reflecting local land use)

Citations used in this Summary:

Baker, C.H., Jr., 1967a. Geology and ground water resources of Richland County, Part 1, Geology: North Dakota Geological Survey Bulletin 46 and North Dakota State Water Commission County Ground Water Studies 7, 45 p.

Cowdery, T.K. and K. Goff, 1994. Nitrogen concentrations near the water table of the Sheyenne Delta aquifer beneath cropland areas, Ransom and Richland Counties, North Dakota: Proceedings of the North Dakota Water Quality Symposium, Fargo, North Dakota, March 30-31, 1994, North Dakota State University Extension Service, p. 89-102.

Downey, J.S. and Q.F. Paulson, 1974. Predictive modeling of effects of the planned Kindred Lake on ground-water levels and discharge, southeastern North Dakota: USGS Water-Resources Investigations 30-74, 22 p.

Harkness, R.E., N.D. Haffield, and G.L. Ryan, 1988. Water resources data, North Dakota, Water year 1987: USGS Water-Data Report ND-87-1, 392 p.

Paulson, Q.F., 1964. Geologic factors affecting discharge of the Sheyenne River in southeastern North Dakota: USGS Professional Paper 501-D, p. D177-D181.

Rorabaugh, M.I, 1960. Use of water levels in estimating aquifer constants in a finite aquifer: International Association of Scientific Hydrology, Publication 52, p. 314-323.

Baker, C.H. Jr. and Q.F. Paulson, 1967. Geology and ground water resources of Richland County, North Dakota, Part III—Ground water resources: North Dakota Geological Survey Bulletin 46 and North Dakota State Water Commission County Ground Water Studies 7, 45 p.

Abstract

Water supplies in Richland County are obtained mainly from ground water. The most important sources are the shoreline deposits of glacial Lake Agassiz. These deposits contain two main aquifers—identified as the Sheyenne delta aquifer and the Hankinson aquifer, which have a combined area of about 400 square miles. They consist of well-sorted deposits of sand that are at least 50 feet thick in most places and as much as 100 feet thick near the western boundary of the county. Grain-size analyses indicate possible well yields of at least 50 gallons per minute in most places and as much as 1,000 gallons per minute in a few places. The aquifers are relatively undeveloped and water levels are only a few feet below land surface. The Sheyenne delta aquifer contains an estimated 4 million acre-feet of ground water in storage and receives about 50,000 acre-feet of recharge during a year of average precipitation. The water in the Sheyenne delta and Hankinson aquifers generally contains less than 500 parts per million dissolved solids, and, although hard, is usable for most purposes.

Aquifers of less importance are associated with the till deposits, and in the bedrock formations, chiefly the Dakota Sandstone. The aquifers in or associated with the till generally are smaller and less productive. Aquifers in the bedrock yield water that is of rather poor chemical quality. However, wells developed in these sources may be capable of yielding 500 gallons per minute in places.

Findings

- Water from the Dakota Sandstone in Richland County is highly mineralized and the TDS is generally more than 2,500 ppm. Most wells produce @ 5 gpm. Largest production is from Wahpeton municipal wells (35-50 gpm).
- Drift aquifers in Richland County: Sheyenne Delta deposits and Lake Agassiz beach deposits. Some water may be obtained from the silt unit that locally composes the upper part of the lake-floor deposits.
- Sheyenne Delta covers about 750 square miles, of which 500 square miles is in northwestern Richland County. The water-bearing portion of the delta in Richland County has an area of about 300 square miles.
- Maximum thickness of delta deposits is 200 feet but the average thickness in Richland County is about 100 feet (Baker, 1966b). In Richland County, the deposits can be divided into three units:

  (1) a lower unit of silt interbedded with clay and sand, which is thickness near the eastern margin of the delta and thins westward;

    a. The lower silty unit is more than 150 feet thick at the eastern edge of the delta, less than 50 feet thick near the Richland-Ransom County boundary, and is entirely absent near the western edge of the delta in Ransom County

  (2) an upper unit of well-sorted sand, which is thickest in the west and thins eastward;

    a. The sand unit is as much as 100 feet thick near the Richland-Ransom County boundary, and is entirely absent near the eastern edge of the delta in Ransom County.
    b. Its average thickness in Richland County is about 60 feet.
    c. The grain size of the sand generally decreases eastward from medium and coarse along the Richland Ransom County boundary to very fine in the eastern part of the delta near Walcott

  (3) a thin layer of wind-blown sand, which covers the entire delta.

    a. The thickness of the wind-blown surficial sand is generally less than 10 feet but may be as much as 50 feet in the highest dunes.
- The upper unit of well-sorted deltaic sand and the overlying deposits of wind-blown sand form the main part of the Sheyenne Delta aquifer—the lower silt unit is generally too fine grained to yield water to wells.
- Water table fluctuates considerably but most of the time and in most places it is less than 10 feet below the surface.
- The water table usually is lowest in late winter, just before the spring thaw. During spring thaw there usually is a sharp rise in the water table and the yearly high often occurs within a month or two after the yearly low, changing from 5—10 feet below ground surface to 1 - 5 feet below ground surface during April.
- Following the high in spring or early summer, the water levels generally decline through the summer, fall, and winter. However, unusually large amounts of precipitation in the summer or fall will cause a lessening in the rate of decline or may even produce slight rises in water levels.

- Winter precipitation has little or no immediate effect because the frost in the ground impedes the infiltration of water. Also, there is little precipitation and that mainly is in the form of snow.
- The Sheyenne River is eroded as much as 120 feet below the surface of deposition of the deltaic sediments. Accordingly, the water table slopes toward the Sheyenne valley and toward the delta edges.
- To 1966, no large capacity wells had been drilled in the delta deposits in Richland County—consequently no aquifer tests have been performed as of 1966. Lake Agassiz beach deposits northwest of Hankinson are noted to be similar in character to the deposits of the Sheyenne delta. An aquifer test near Hankinson yield: T = 18,000 gpd/ft, Sy = 0.17 (Powell, 1956, p. 20). 52 hours of pumping.
- Estimates of T from grain size using method of Keech (1964) (5 locations) resulted in 30,000 gpd/ft near the Richland-Ransom County boundary where the upper sand unit is more than 100 feet thick to less than 500 gpd foot in the southeastern part of the delta where the upper unit is absent.
- Porosity of cores of deltaic sand deposits ranged from 40 to 48 percent and averaged 43 percent.
- Specific yield of four cores ranged from 25 to 40 percent (noted to seem “rather high” for deltaic sand deposits as a whole but may be representative for the coarser facies).
- Estimate of specific yield for the upper part of the deposits made by comparing the rise in water levels in observation wells with precipitation. An average rise of 3.4 feet in 22 wells was attributed to April rains and to a lesser extent by snow melt. The average storage for the upper deposits was estimated to be no greater than 10 percent.
- In summary, the specific yield for the more permeable (and deeper) delta deposits is likely higher than the average for the delta deposits as a whole.
- In spring of 1964, an estimated 50,000 acre-feet was recharged over 192,000 acres (3.12 inches). This was considered to be representative of normal spring conditions (based on the changes in water levels in a well that is measured weekly since 1937.
- The amount of water discharged from the Sheyenne delta through wells is very small compared to natural discharge—the largest yield of any well in Richland County is the municipal well at Wyndmere, which yields about 50,000 gpd.
- Discharge through springs is large but difficult to make an accurate estimate of.
- For the 5-year period 1957-1962, the average increase in the Sheyenne River flow for the reach Lisbon to Kindred for October through February was 0.16 cfs per mile of river. Groundwater is attributed to the increase because of low runoff conditions during this period.
- In spring and summer months the difference in discharge between Lisbon and Kindred is often as great as 100 cfs. Precipitation, runoff, and evapotranspiration are important considerations during this period.
- Discharge of groundwater through springs (numerous) along the eastern edge of the delta may be 5 to 10 times as great as the fall and winter discharge to the Sheyenne River. Even so, annual discharge through springs is probably less than half of the estimated annual recharge.

- Hankinson aquifer consists of higher beaches of Lake Agassiz that form a broad belt of sand and gravel extending from the Wild Rice River (north of Hankinson) southeastward to the South Dakota border. The deposits are separated from the Sheyenne delta by an area of till and lake clay.
- Coarser deposits of Hankinson aquifer are near the south end of Richland County and the material becomes finer grained toward the north. Aquifer test at Sec. 2 T. 130 N, R. 50 W had reported transmissivity of 18,000 gpd/ft, Sy of 0.17 and hydraulic conductivity of 24.4 ft/day (thickness @ 100 feet). Recharge is by direct precipitation and discharge (natural) is mostly by evapotranspiration with some springs at the foot of the higher slopes.
- City of Hankinson has two municipal wells that tap Hankinson aquifer. Capacities of 500 to 550 gpm.
- Several small beach aquifers lie outside the Hankinson aquifer. These isolated aquifers are only a few feet thick and a few tens of feet wide but they are highly permeable and will yield small quantities of water to shallow, large-diameter wells. They are recharged by precipitation.
- About 450 square miles in northeastern Richland County is covered by lake-floor deposits, mostly of clay but in some places the upper part is composed of silt. Silt facies are generally less than 10 feet thick—will yield small quantities of water to large-diameter wells. Unconfined. Generally, water cannot be obtained from the clayey facies of the lake-floor deposits.
- Four major till aquifers in Richland County:

  (1) Milnor channel (shallow valley that extends from Sheyenne valley in Ransom County to the vicinity of Lake Traverse in South Dakota—represents an ice-marginal Pleistocene stream. Sand, sandy gravel, and sandy silt 8 to 66 feet thick and average 40 feet thick. Under unconfined conditions and water levels are generally within 10 feet of surface. Recharge is from precipitation and interaquifer movement form Brightwood aquifer)

  (*2) Brightwood aquifer*: thick body of glacial outwash enclosed by stagnation moraine. About 13 square miles, crops out in high steep face near Elsie on west side of Milnor channel in Brightwood Township. Most outwash is above level of Milnor channel. Thickness ranges from 70 to 130 feet and averages 100 feet. Coarse sand to medium gravel, well sorted. Deposits are only partly covered by till and water is under unconfined conditions. Water discharges into adjacent lakes with elevations below the top of the deposit. Water level is 50 to 65 feet below ground surface. Four feet annual water level fluctuation in 1965. Laboratory hydraulic conductivities are 86 to 160 ft/day. Recharge is from local precipitation. Estimated Sy is 30 percent.

  (3) Fairmount aquifer: Buried outwash near Fairmount. Depth of 80 to 110 feet, thickness of 9 to 18 feet, fine to medium gravel overlain by fine clayey sand, under artesian conditions with water level near ground surface. 24 hour pumping test in Fairmount village wells in 1956 at 145 gpm—T=2,500 gpd/ft and storage coefficient = 0.00035. Recharged by overlying till and underlying Dakota Sandstone.

  (4) Colfax aquifer: Near Colfax. Sand 100 to 150 feet below surface. @ 50 feet thick, probably buried outwash.

Citations used in this Summary

Baker, C.H., Jr., 1966b. Geology and ground-water resources of Richland County, North Dakota, Part II, Basic data: North Dakota Geol. Survey Bull. 46 and North Dakota State Water Comm. County Ground Water Studies 7, 170 p.

Keech, C.F., 1964. Ground-water conditions in the proposed waterfowl refuge area near Chapman, Nebraska: USGS Water-Supply Paper 1779-E, 55 p.

Baker, C.H., Jr., 1966. Geology and ground-water resources of Richland County, North Dakota, Part II, Basic data: North Dakota Geol. Survey Bull. 46 and North Dakota State Water Comm. County Ground Water Studies 7, 170 p.

Summary

This is a compendium of water-quality data, well construction information, and well logs for Richland County. Includes map of well locations. Cited in other reports.

Baker, C.H., Jr., 1967. Geology and ground water resources of Richland County, Part 1, Geology: North Dakota Geological Survey Bulletin 46 and North Dakota State Water Commission County Ground Water Studies 7, 45 p.

Abstract

Richland County comprises an area of approximately 1,450 square miles in the southeastern corner of North Dakota. About one-fifth of the county is in the Drift Prairie physiographic division; the remainder is in the Red River Valley (basin of glacial Lake Agassiz) physiographic division.

The stratigraphy of the sedimentary rocks underlying the Pleistocene deposits is relatively uncomplicated. Cretaceous Dakota Sandstone lies unconformably on the Precambrian crystalline basement. The Graneros Shale and the Greenhorn Formation, both of Late Cretaceous age, overlie the Dakota in most of the county, and no indurated rocks younger than the Greenhorn are present.

Pleistocene glacial drift mantles the entire county; the known thickness of the drift, including the deposits of glacial Lake Agassiz, range from 154 to 490 feet. Drift representing several ice sheets may be present but cannot be differentiated except in a few places. All of the surficial features of the county can be attributed to the last ice sheet (Mankota advance); local zones of oxidized till, extensive bodies of buried outwash, and buried lake silts are the only indications of the presence of older drift in the subsurface.

The major surficial features of the Drift Prairie in the county are stagnation moraine, a large body of overridden pitted outwash, and an ice-marginal drainage channel. Minor features include end moraine, ground moraine, and kames.

The flat expanse of the Red River Valley is interrupted by the Sheyenne delta and by the major shorelines of glacial Lake Agassiz. The Sheyenne delta is an extensive deposit in Richland County and an important aquifer. It covers 550 square miles and consists of sand and silt as much as 200 feet thick. The lake-floor deposits, where present, may include two distinct lithologies, but the upper unit is thin and irregularly distributed.

Few Pleistocene fossils have been found in Richland County, and most of the available material is of little value for age determinations.

Summary

! Richland County is in the Central Lowland province of the Interior Plains. The eastern part of the county is in the Red River Valley physiographic division and 300 square miles in the southwestern part of the county is in the Drift Prairie physiographic division. The Red River Valley can be divided into the Sheyenne delta, which occupies approximately 550 square miles in the northwestern corner of the county and the Lake Agassiz plain.

! The north end of the Sheyenne delta stands about 100 feet above the lake plain; the delta grades outward into the plain. The delta surface includes many areas of dunes where the local relief is as much as 50 feet within a square mile. Outside of the dune areas, the ground is gently rolling to nearly flat. The Sheyenne River crosses the delta in a steep-sided valley that is as much as 120 feet deep.

! Much of the Drift Prairie is an area of high relief (50 to 75 feet in a square mile) and nowhere does it approach the levelness of the lake plain.

! drainage pattern on the Sheyenne delta is poorly developed. Antelope Creek, Elk Creek, and several smaller unnamed streams drain into the Wild Rice River. A number of unnamed streams enter the Sheyenne River from the delta—most of these minor streams are only a few miles long and although spring fed, some are dry during a part of every year. Good subsurface drainage precludes the existence of permanent ponds on the delta but marshy areas are numerous in wet seasons.

! Most of the soil is of the chernozem type, characterized by black topsoil and limey subsoil. The soils of the Sheyenne delta and the higher beaches are sandy loams, much lighter than the clayey loams. These light soils are subject to wind erosion when plowed and the dune topography makes cultivation difficult. Accordingly, much of this area is used for grazing. A portion of the Sheyenne delta is in the Sheyenne National grassland, administered by the United States Forest Service and is restricted to grazing.

! Climate is continental in type, characterized by short summers and long cold winters. Summer temperatures above 90-degrees are common and winter temperatures are often as low as 20-below. The average annual precipitation is about 20 inches, most of which falls as rain in the spring and summer.

! Stratigraphic sequence (USGS Nomenclature):

Age	Unit	Description	Thickness (feet)
Quat (recent)	Alluvium	Silt and clay on flood plains of modern streams	0-40
Quat (Pleist)	Glacial Drift	Glacial till, glaciofluvial deposits, and glacial lake sediments	154-490
Cretaceous	Greenhorn Fm.	Black limey shale, generally contains minute white “specks” of calcium carbonate; interbedded with white to buff limestone	0-212
Cretaceous	Graneros Shale	Black shale, locally with streaks and lenses of white sand; often marine fossils	0-160
Cretaceous	Dakota Sandstone	White quartz sand with interbedded variocolored sandy shale, siltstone, and clayey sandstone	0-238+
Cretaceous (?)	Undifferentiated rocks	Light gray to moderate yellowish-green “nodular” sand, interbedded with varicolored clay	0-61
Precambrian	Undifferentiated crystalline rocks	“Granite.” Generally deeply weathered in upper part	?

! Geologic History (Pre-Pleistocene):

(1) Much erosion of Precambrian crystalline rocks exposed at the beginning of Cretaceous. Williston Basin was slowly sinking and filling with sediments (Richland County is on the edge of the basin and was probably a source area for the basin sediments.

(2) Cretaceous seas invaded area, covering an irregular and deeply weathered surface. Advance of sea was slow and very shallow water covered the area. Oldest sedimentary rocks in the area are littoral deposits of the Dakota Sandstone and their irregular distribution and varying thickness suggest that many knobs and hills of the granite protrude as islands in the shallow sea. The sea probably retreated briefly after deposition of the Dakota sand and erosion probably removed much of the deposit from the eastern part of the county.

(3) Later, water completely covered the area and black mud (Graneros Shale) was deposited in quiet, brackish water. A few thin beds and lenses of fine sand suggest that the shoreline was not far away. Younger deposits (Greenhorn Formation) contain much interbedded limestone and were probably formed in somewhat deeper water with better circulation. Younger Cretaceous rocks that are present further west (Niobrara, Pierre and other formations) are absent under Richland County. Probably at least some of these rocks were deposited in the area but were subsequently eroded.

(4) After the retreat of the Cretaceous seas, the area again was subjected to erosion. Many of the Cretaceous rocks were stripped away and the weathered basement rocks were exposed again in the deepest valleys. This last long period of erosion was terminated with the advance of the Pleistocene glaciers.

! Geologic History (Pleistocene)

(1) During Pleistocene, Richland County was covered several times by sheets of glacial ice. Each ice sheet probably left deposits of drift and each succeeding ice sheet probably removed and redistributed part of the deposits of its predecessor. The deposits of the various ice sheets are so similar in lithology that there is no ready means of distinguishing between them. Great thicknesses of glacial drift were deposited and by the time of the last glacial retreat the original topography was completely buried. A portion of the last ice sheet broke off and melted in place and the stagnant ice left characteristic topographic features in the southwestern corner of Richland County. The stagnant ice deposits were overridden by a minor readvance of the glacier and then the final withdrawal of the ice began.

(2) The regional slope in eastern North Dakota is to the northeast as the last ice sheet retreated to the north it blocked the drainage. A large proglacial lake (Lake Agassiz) was formed in eastern North Dakota and western Minnesota. Most of Richland County is within the Lake Agassiz basin. At its maximum, Lake Agassiz extended from northeastern South Dakota to northern Manitoba (more than 550 miles) and had an average width of 150 miles. The greatest depth of Lake Agassiz in Richland County (difference between lowest point on the lake plain and the highest beach) was about 150 feet. The lake had an outlet to the south through a channel now occupied by the Bois de Sioux River and a chain of lakes and marshes. Water flowing out of the lake eroded the bottom of the channel and this deepening of the outlet caused a general lowering of the water level in the lake. The materials in the floor of the channel were not homogeneous; consequently the rate of erosion was not uniform. During periods of rapid erosion, the lake level fell rapidly; during periods of slow erosion, the lake level changed slowly and well-defined shorelines were formed. As the ice continued to retreat, lower outlets were uncovered to the northeast and Lake Agassiz gradually receded from Richland County. Possibly a readvance of the glacial ice blocked the northern outlets anc caused the lake to be refilled to the level of the southern outlet. The effect of the draining and refilling was slight in Richland County; a few scattered deposits of silt on the lake plain may have been deposited during the second stage of the lake.

(3) Many of the surficial features of Richland County were formed in Lake Agassiz. During the highest stage of the lake, a well-defined shoreline (Herman shoreline) was formed and an extensive delta was formed at the mouth of the Sheyenne River. As the ice sheet dwindled and the lake was drained, other beaches were formed at lower levels and parts of the courses of four of these lower beaches can be traced through Richland County. During the life of Lake Agassiz, wave action smoothed the lake floor and a blanket of clay and silt was deposited in the deeper parts of the basin.

(4) When the glacial ice far to the north finally melted and Lake Agassiz was drained, the lake plain had essentially the form that is seen today. Recent erosion has been very slight

and the only conspicuous topographic change in Richland County since the drainage of the lake has been the formation of sand dunes on the Sheyenne delta and in the vicinity of Hankinson. These dunes probably were formed very soon after the drainage of the lake and have changed little in recent times.

- Sheyenne Delta: covers about 750 square miles, of which 550 is in Richland County. It is crossed by the Sheyenne River, which is deeply entrenched into the delta. The northeastern edge of the delta is marked by a conspicuous steep slope, prominent at the Cass-Richland County boundary but it becomes less prominent southward and is barely visible south of Colfax. Near Wyndmere, there is no surface expression of the delta edge and the limits of the delta must be mapped on the basis of the changes in lithology.
- Sheyenne Delta surface is covered with sand dunes over much of its extent and the topography is strongly rolling. The highest dunes border the Sheyenne valley, were the local relief may exceed 50 feet. Most of the dunes are stabilized by vegetation but there is considerable movement of sand wherever the vegetal cover is broken.
- Near the Richland-Ransom County boundary, the delta sediments are primarily fine to medium sand but the average grain size decreases eastward. Near the eastern edge, the predominant lithology is very fine sand and silt with some interbedded clay.
- Stratification is well exposed in only one known locality, near the eastern edge of the delta (west edge of sec. 14, T. 136 N, R. 51 W). Here fine sand, silt, and clay are interbedded and the sand and silt are cross stratified. The most common type of stratification is ripple lamination. Some silt and very fine sand beds are strongly contorted on a small scale. The mode of formation of these contortions is not known but such contortions as well as the ripple laminations are common features of deltaic and flood-plain deposits.
- An advancing delta is built out over its own bottomset beds as well as over existing lake-floor deposits and it is impossible to distinguish in test holes between delta bottomsets and lake-floor deposits of essentially the same composition; therefore a boundary cannot be established between delta and lake-floor deposits.
- The greatest thickness of sand penetrated during test drilling on the Sheyenne delta was 107 feet in test hole 2185 (135052-21ccc) but it is questionable whether this figure should be taken as the thickness of the delta deposits at this point—the drill passed from sand into silty clay and the hole was stopped after drilling only a few feet into the clay before reaching the underlying till. The greatest known thickness of sand, silt, and clay; that is, the greatest known depth to glacial till is 198 feet penetrated in test hole K-2R (136-51-7ddd). The average depth to till is 150 feet. The delta sand is only 45 feet thick near the southern edge of the delta and has no clay or silt under it.
- the steep northeastern slope of the delta is probably a wave-cut slope representing the Campbell shoreline. The entire delta must have been formed before the lake declined to the Campbell level.

Armstrong, C.A., 1982. Ground-water resources of Ransom and Sargent Counties, North Dakota: North Dakota Geological Survey Bulletin 69—Part III and North Dakota State Water Commission County Ground-Water Studies 31—Part III, 51 p.

Abstract

Groundwater in Ransom and Sargent Counties is available from glacial-drift aquifers of Quaternary age and from the Dakota aquifer system of Cretaceous age. Glacial-drift aquifers with the greatest potential for development are the Spiritwood aquifer system and the Bramptom, Elliott, Gwinner, Elglevale, Milnor Channel, Oakes, Sheyenne Delta, and Sand Prairie aquifers. Properly constructed wells in the more permeable parts of these aquifers will yield from 500 to 1,5000 gallons per minute. A total of about 3,000,000 acre-feet of water is available from storage in the glacial-drift aquifers.

Water from the glacial-drift aquifers varies in chemical quality. Dissolved solids concentrations in samples from these aquifers range from 203 to 4,670 milligrams per liter.

The top of the Dakota aquifer system underlies Ransom and Sargent counties at depths that range from 500 to 1,000 feet below land surface. Water in the Dakota is under sufficient head to flow at land surface in most parts of the two-county area. Unrestricted flows from wells tapping the aquifer system generally are less than 10 gallons per minute but may be as much as 50 gallons per minute. Water in the Dakota aquifer system generally is a sodium sulfate type and has dissolved-solids concentrations ranging from 2,170 to 3,340 milligrams per liter.

Summary

! Climate: subhumid. The mean annual precipitation at Lisbon is 20.19 inches. About 70 percent of the precipitation occurs from April through August. Most of the summer precipitation is from thunderstorms and is extremely variable both in area and in magnitude. The mean annual temperature is 41.8 F. Summer daytime temperatures usually are warm, ranging from 75 to 85. Temperatures exceeding 90 are common in summer. Daily low temperatures are blow o during winter months, especially in January and February.

! Natural surface drainage in the Lake Agassiz Plain is nearly nonexistent except near the Sheyenne and Wild Rice Rivers, which flow through the Sheyenne Delta. Short tributaries to these rivers have formed, but they only carry runoff for short periods following large storms.

! Sheyenne delta occupies about 750 square miles in Richland, Cass, Ransom, and Sargent Counties in eastern North Dakota. Approximately 230 square miles of delta is in Ransom and Sargent Counties.

! Surface area of the delta is generally composed of deltaic materials with thin soils. Shallow depressions of 1 to 10 feet deep and sand dunes as much as 85 feet high have been formed by wind action.

! The delta deposits in Ransom and Sargent Counties grade from predominantly medium to coarse sand with some lenses of gravelly sand and finer sand and silt in the southwest to predominantly fine to medium sand with a larger proportion of fine sand and silt lenses in the north and east. In the Sheyenne River valley the delta deposits have been removed by erosion and have been replaced by fine-grained alluvial deposits consisting of fine

sand, silt, and clay beds. The thickness of the delta deposits ranges from 0 at the edges to as much as 95 feet at test hole 136-053-25aaa. The saturated part of the aquifer ranges in thickness from 6 to 87 feet and has a mean saturated thickness of 41 feet. Downey and Paulson (1974) reported thicknesses as great as 140 feet and a mean thickness of 97 feet; most of their data were from Richland County so apparently the deposits not only are finer grained in an eastern direction, but also are thicker.

! Yields form individual wells should range from a few gpm near the western edge and the alluvial areas to about 1,000 gpm in areas were more than 35 feet of gravelly sand exists. Variations in yield within short distances may be large, as discovered by a few prospective irrigators who have drilled two to five test holes in the same quarter section before fining a sufficient thickness to yield enough water to supply a pivot system. However, most of the area will yield more than 250 gpm. The yield range for most of the Sheyenne Delta aquifer is 250 to 1,000 gpm because variations in thickness and transmissivity make closer estimates impractical.

! Recharge to the aquifer generally is from precipitation and snowmelt that infiltrates directly through the sandy soil to the aquifer and from flowing wells in the Dakota. Most of the recharge from precipitation occurs in the spring during the time the frost leaves the ground and before the evapotranspiration loss to maturing crops and high temperatures become significant. Significant recharge also occurs at other times, such as during two storm periods (June 19 and 20, 1975 and June 29 and 30 1975) when more than 5 inches of rain fell during each storm. A digital model of part of the delta area indicates that from 6 to 8 inches of precipitation recharges the aquifers.

! Water levels rise in the spring due to snowmelt, precipitation, and the release of water from the frost zone. The rise is followed by a sharp decline during the summer months due to evapotranspiration (this sharp decline may be interrupted by large storms). The sharp decline is followed by a more gradual decline that occurs during the autumn season when evapotranspiration is lower and during the winter when capillary water or vapor above the water table is frozen in the soil. Unusual quantities of late fall precipitation can cause water-level rises during the early part of the winter.

! The gradient of the potentiometric surface in the Sheyenne Delta aquifer is toward the Sheyenne River in areas within a few miles of the river. The steepest gradients are beneath the bluffs on each side of the river valley. Two to 5 miles beyond the river valley, regional gradients become low and local gradients, which are toward individual low areas where evapotranspiration is greatest, mask regional trends.

! Discharge is by evapotranspiration, pumpage, and underflow into the Sheyenne River and its tributaries in the delta. In 1977, about 830 acre-ft of water was pumped from the Sheyenne Delta aquifer in Ransom and Sargent Counties.

! The Sheyenne River is a gaining stream throughout the delta area of Ransom and Richland Counties. The gain in Ransom county was about 14 cfs in the fall of 1963. Precipitation in 1963 was about 90 percent of normal so the measured gain probably was lower than would be expected during a year of normal precipitation.

- In a normal precipitation year, between 1 and 3 inches of the 6 to 8 inches of precipitation that infiltrates to the aquifer as recharge eventually becomes streamflow. The remainder is lost to evapotranspiration.
- Water from the Sheyenne Delta aquifer is a calcium bicarbonate type. TDS from 28 wells ranged from 203 to 1,150 mg/l with a mean of 386 mg/L. Specific conductances ranged from 400 to 1,700 umho/cm.
- Sheyenne Delta aquifer has a mean saturated thickness of 41 feet in Ransom/Sargent Counties and an estimated specific yield of 0.15.
- The city of Lisbon obtains its water from two wells completed in Sheyenne River alluvium or undifferentiated glacial outwash. The maximum possible well yield was not reported but one well was tested at 550 gpm for 20 hours. Reported daily use in 1976 was about 184,000 gallons. A water sample was collected from each well and analyzed—TDS of 773 and 1,060 mg/L; sulfate of 240 and 330 mg/L.

Armstrong, C.A., 1979. Ground-water basic data for Ransom and Sargent Counties, North Dakota: North Dakota Geological Survey Bulletin 69—Part II and North Dakota State Water Commission County Ground-Water Studies 31—Part II, 637 p.

Summary

This is a compendium of water-quality data, well construction information, and well logs for Ransom and Sargent Counties. Includes map of well locations. Cited in other reports.

Bluemle, J.P., 1979. Geology of Ransom and Sargent Counties, North Dakota: North Dakota Geological Survey Bulletin 69—Part I and North Dakota State Water Commission County Ground-Water Studies 31—Part I, 84 p.

Abstract

Ransom and Sargent Counties, located at the eastern edge of the Williston Basin are underlain by 500 to 1,800 feet of Paleozoic and Mesozoic rocks that dip gently to the northwest. The Cretaceous Belle Fourche, Greenhorn, Carlile, Niobrara, and Pierre Formations lie directly beneath the glacial drift, and the Sheyenne River, especially in northwestern Ransom County. The Pleistocene Coleharbor Group, which covers most of the area, consists mainly of glacial, fluvial and lake sediment. The Coleharbor Group averages about 200 feet thick but it is as much as 400 feet thick near Gwinner. The Holocene Oahe Formation occurs in parts of the area, chiefly sloughs, river bottomland, and dune fields. It consists mainly of alluvial and eolian sediment.

Most of the two-county area is part of the Glaciated Plains, an area characterized by nearly level to undulating topography. Rolling to steep land is found along the Sheyenne River valley, on the Prairie Coteau in southeastern Sargent County, in areas of sand dunes in the eastern

part of Ransom County, and western Sargent County, and in areas of intense ice thrusting, which are prominent in western Sargent County.

Several distinct till layers that have been identified in Ransom and Sargent Counties attest to repeated glacial advances, both prior to and during Wisconsinan time. Following the earliest flooding of western Sargent County by glacial Lake Dakota, a readvance of the glacier resulted in large-scale thrusting. The early glacial Lake Agassiz flooded eastern parts of the two counties, resulting in discontinuous lake and shore sediments above the Herman level. Later, the Sheyenne Rive built a large delta into the lake while it stood at the Herman level. After r Lake Agassiz drained, wind erosion built large dunes on the Sheyenne Delta.

Summary

- Beneath the youngest sediments (alluvium and windblown silt) are glacial deposits belonging to the Coleharbor Group, which overlie the Cretaceous Greenhorn, Carlile, Niobrara, and Pierre Formations.
- Sediment of the Coleharbor Group is exposed throughout Ransom and Sargent Counties. The Colharbor Group in the two counties apparently ranges up to more than 400 feet thick beneath the Whitestone Hills.
- Holocene sand and silt facies of the Oahe Formation in Ransom and Sargent Counties consists of river and windblown sediment. The river sediment is found beneath flood plains along the Sheyenne, Maple, and Wild Rice Rivers and along some of the smaller streams as well. It is generally light to dark gray sand and silt that has indistinct horizontal bedding. Terrestrial and aquatic fossils such as shells, wood fragments, and bones are common.
- Windblown sediment is extensive in eastern Ransom County and in parts of western Sargent County. It is typically well-sorted, fine sand with some black, sandy silt that was derived from windblown topsoil. Obscure bedding, indistinct cross-stratification, and weak paleosols can be seen in some exposures. Fossils are uncommon. The windblown sediment, which occurs as dunes or as a nearly flat sheet of sand, generally overlies fluvial sediment of the Colharbor Group (sand and gravel facies), but in some places dunes have blown over areas of till.
- The Sheyenne River valley crosses Ransom County and includes about two percent of the two-county area. It is about 200 feet deep near Fort Ransom and in that area it has steep, bouldery walls cut mainly in till and in the Cretaceous Niobrara and Pierre Formations. The valley is only about 50 feet deep in eastern Ransom County were it is cut into fine sand and silt of the Sheyenne Delta but over a mile wide in places.
- It is sometimes difficult to differentiate the sheets of shoreline sand from fluvial deposits. Both types of sediment are closely associated in many places. In the westernmost portions of the Sheyenne Delta, interbedded lake and stream sediments are commonly seen in close association; farther east in Ransom County most of the surface cuts expose stream sediment and the interbedded lake and stream sediment occurs at slightly greater depths.

- The Sheyenne Delta deposits consist of interbedded lake sediments and river sediments in places and they are covered by a sheet of windblown sand and dunes in places, but river sediment constitutes the largest proportion of the surface materials in the delta.
- The meltwater trench of the Sheyenne River was mainly carved by water draining from glacial Lake Souris in north-central North Dakota into glacial Lake Agassiz. At the point were this large river of meltwater flowed into Lake Agassiz, it built a delta. It is not known for certain whether the flow was relatively continuous or whether it was a series of periodic, "catastrophic" events. The water flowing out of glacial Lake Souris was probably relatively free of sediment (the sediment having settled out in the lake) and cold and therefore capable of intense erosion; it probably carved the Sheyenne River trench quite rapidly. Evidence of repeated flooding is found in the form of patches of bedded silt in several places on the rim of the Sheyenne trench.
- Gravel terraces occur within the Sheyenne meltwater trench in several places along its route.
- Most of the gravel and sand of the river flood plains and terraces is poor in quality, tending to be silty and shaly. The best quality gravel and sand is found on some of the terraces of the Sheyenne River. River terrace gravel contains somewhat less shale and is better sorted than is the river sediment found in meltwater trenches and broad glacial outwash plains.
- Much of the information on the Sheyenne Delta is the result of research by Dr. John Brophy of the Geology Department at North Dakota State University in Fargo. Dr. Brophy has done much more work on the delta than has anyone else.
- The delta is characterized by a generally low-relief, east- to northeast-sloping surface that is covered by irregular, partly stabilized hills of windblown sand. Local relief on some of the dunes exceeds 75 feet. The Sheyenne River valley is entrenched as much as 100 feet below the delta surface and exposes an incomplete cross section of the deltaic stratigraphy. The northeast edge of the delta is marked by a 75-foot high, wave-curt scarp that becomes less pronounced southward.
- Generally the lowermost sediments lying on the pre-delta till surface in Ransom and Sargent Counties are gravel and sand deposits that occur in T 132-133N, R 53-54W. These fluvial sediments apparently were deposited by the early Sheyenne River as soon as it abandoned its ice-marginal Milnor Channel position when the glacier margin receded from this four-township area. The gravel and sand is the deepest fluvial sediment in the area, with between 5 and 15 feet of it lying on till at elevations between 950 and 975 feet; these buried fluvial sediments apparently have no lateral equivalent in the two-county area.
- Along the western margin of the delta, in T 133-136 N, R 54W, in Ransom County, sand overlies the till in most places at elevations ranging rom about 1,025 to 1,050 feet. These sand deposits are restricted to the location where the river entered the rapidly flooding lake. They become much finer just a short distance eastward, grading into silt and clay, which generally overlies till, but is itself buried in most places beneath windblown materials. The silt-clay unit is largely turbidity-current sediment, which ranges up to over 70 feet thick in parts of eastern Ransom County and is exposed in several places along the Sheyenne River trench.

- Broad areas of the Sheyenne Delta in eastern Ransom County and parts of the glacial Lake Dakota plain in western Sargent County have been subject to intense erosion and deposition by the wind since deglaciation. Wind-blown sediment consists of well-sorted, fine sand with no gravel. Indistinct cross-bedding is found in some dunes. The many dunes and shallow blowouts on the Sheyenne Delta impart a hummocky appearance to the landscape. Dunes about 25 feet high are common with some over 75 feet high near the Sheyenne River in eastern Ransom County.
- The dunes on the Sheyenne Delta lie mainly in the area opposite the old mouth of the Sheyenne River and along both sides of the east-west stretch of the Sheyenne trench. The dunes of the wedge-shaped area spreading from the old mouth of the Sheyenne River represent wind reworking of sandy delta beds but at least some of the dunes along the trench may have originated from river sand laid down during the cutting of the trench. Prevailing wind direction during dune formation appears to have been from the south, although recent blowouts in the area indicate northwesterly winds.
- With the development of vegetation cover, the dunes became more stable, but they are still subject to wind erosion and redeposition wherever the cover is broken. The pattern of eolian activity and resultant distribution of dunes on the Sheyenne Delta seems to be controlled by the presence or absence of a layer of clay that is less than a foot thick in most places where it occurs on top of the ground. Wherever the clay is present, it forms a protective seal, effectively preventing wind erosion; where it is lacking, the sand is free to blow. Groundwater discharge has carried the clay upward, apparently from buried layers of turbidity-current sediment, and deposited it on the surface (??huh??). In some places, the wind has scoured to the water table, which also acta as a barrier to further downward erosion by the wind.

Sieg, C.H. and P.M. Wolken, 1998. Dynamics of a threatened orchid in flooded wetlands (DRAFT): submitted to 16th North Am. Prairie Conference, July 26-29, 1998, Kearny, NE, 21 p.

Abstract

One of the three largest metapopulations of the western prairie fringed orchid (*Platanthera praeclara)* occurs on the Sheyenne National Grassland, in southeastern North Dakota. Our study was initiated in 1993 to quantify the effect of flooding on individual orchid plants. A total of 66 plants (33 flowering and 33 vegetative) growing in standing water were permanently marked in 1993; their status was checked at the end of the growing season in 1993 and in subsequent growing seasons (1994-1996). Most (70%) of the flowering plants persisted through the 1993 growing season; those that did not were shorter (P=0.001) and had a higher percentage of their stalk submerged through the growing season (P<0.02). Only one vegetative plan persisted through the 1993 growing season. The ability of the flowering plants to persist in standing water was attributed to their greater height which allowed some portion of the plant to remain above the water and produce photosynthates needed to produce next season's shoot bud and immature root system. Flowering plants persisted through the first growing season with as much as 75% of their stalk submerged in water. IN 1994, only four plants reappeared; in 1995 only one plant reappeared aboveground. None of the plants that did not persist through 1993 reappeared in 1994 or 1995. By 1996 none of the marked plants were observed aboveground. Although flooding is detrimental to the survival of vegetative plants, its impact must be viewed in a larger context and include data over several years. It is likely that flooding creates suitable moisture conditions on higher landscape positions, provides and important mechanism for see dispersal, and is one of several natural catastrophic events that plays a significant role in perpetuating these wetland systems and associated species.

Summary

- The western prairie fringed orchid (*Platanthera praeclara)* is a federally listed threatened plant species found in wetlands of the tallgrass prairie west of the Mississippi River. One of the three largest metapopulations of the orchid occurs on the Sheyenne National Grassland in the southeastern corner of North Dakota.
- The western prairie fringed orchid is a perennial plant characterized by erratic aboveground growth and flowering. Periods of high orchid numbers, usually linked with above-average precipitation, are followed by years when the orchids have seemingly disappeared.
- The life history of the western prairie fringed orchid includes two distinct life states: vegetative plants (up to 24 cm tall and having 1 or 2 leaves) that remain vegetative throughout the growing season and flowering plants that develop a hollow flowering stalk early in the growing season and have >10 leaves and average up to 52 cm tall.
- The orchid regenerates vegetatively during the growing season by forming a new primary tuber and perennating bud which develop into the new root system and shoot for the following growing season. In this manner, populations may persist for some time; however, seed establishment is required for recruitment of new individuals.
- Densities of flowering orchids on the Sheyenne National Grassland were positively correlated with soil moisture in the current year and total orchid density was correlated with soil moisture in the current and previous year.
- The Sheyenne National Grassland encompasses 27,244 ha and is managed by the US Forest Service. It is depicted as a tallgrass prairie but a “Sandhill Prairie” is more accurate. Big bluestem (Andropogon gerardii) and little bluestem (Andropogon scoparius) occur through the study area.
- The western prairie fringed orchid occurs most often in lowland depressions (“swales”) associated with the Glacial Sheyenne Delta. A layer of nearly impervious silt interbedded with clay and sand is responsible for the relatively high water table in the swales (attributed to Baker and Paulson, 1967).
- Woolly sedge (Carex lanuginosa Michx.) And northern reedgrass (Calamagrostis stricta (Timm. Koel.)) and baltic rush (Juncus balticus Willd.) Are common in lowland depressions where the orchid occurs. Blue grama, needle-and-thread, sun sedge, and prairie sandreed grow on uplands.
- The exposure to environmental stresses such as flooding may have a carry over effect in subsequent growing seasons. Environmental stresses or damage in a previous season

during which carbohydrate reserves and perennating tissues were formed, or during the beginning of the current growing season when adequate conditions dictate the growth and survival of a new plant were thought to be cures that influenced the reappearance of plants during a growing season.

- timing and duration of flooding influences the survival of flooded plants. In 1993 water depth increased in the swales during the growing season. It is likely that plants would be more likely to persist and flowering plants more likely to produce seeds in years when the flooding occurs early in the growing season and then subsides.
- Few data are available on the long-term impacts of flooding or other stresses on survival of individual plants. Data from this study (i.e. lack of root tissue growth on dormant root systems) indicates that it is unlikely that the plants that did not reappear in 1994 or in subsequent years will ever reappear aboveground in the future.
- "Although this paper documents that flooding has a detrimental effect on the persistence of some individual orchids occurring in the wettest portions of the landscape, we do not suggest that flooding over the last 4 years has destroyed the metapopulation of the western prairie fringed orchid on the Sheyenne National Grassland. To the contrary, we observed high numbers of orchids on the Grassland in 1993 and in subsequent years. Swales that supported orchids during a drought in the early 1990's have been flooded and devoid of orchids since 1993; yet the presence of orchids on higher landscape positions have resulted in a net increase in orchid numbers on the National grassland beginning in 1993." "...flooding also creates habitats with suitable moisture conditions higher on the landscape and then serves to disperse orchid seeds to these habitats."

Paulson, Q.F., 1964. Geologic factors affecting discharge of the Sheyenne River in southeastern North Dakota: USGS Professional Paper 501-D, p. D177-181.

Abstract

Throughout much of its length the Sheyenne River is fed almost wholly by overland runoff from glacial till. However, in the reach 75 to 145 miles upstream from its junction with the Red River of the north, the Sheyenne drains ground water from sand deposits in the Sheyenne delta, into which its valley is deeply incised. Discharge measurements made in the fall of 1963 indicated an average gain of 28.8 cfs in this reach.

Summary

- Sheyenne River drains about 9,300 square miles of eastern Northern Dakota; about 4,000 square miles lies in the closed Devils Lake basin.
- About 10 miles southeast of Lisbon, the Sheyenne enters a broad area of mainly sand deposits that have been described by many workers as deltaic in origin, named the Sheyenne delta (about 800 square miles). The delta is nearly flat in some parts but strongly rolling in others where the sand has been heaped into dunes by wind action. Surface drainage is poorly developed.

- Thickness commonly exceeds 50 feet and in a few places is known to be greater than 100 feet.
- On reaching the delta the Sheyenne River turns northward and flows approximately along the contact between the east edge of the drift prairie and the west edge of the delta. Where it leaves the drift prairie, the river swings eastward across the delta. Compared to the channel along the contact with the drift prairie, the channel across the delta is much more sinuous. The distance measured along a straight line between the west edge of the delta and the east edge is about 23 miles but the distance along the river is about 52 miles.
- The discharge of the Sheyenne River has been measured continuously since March 1938 at Valley City, since September 1956 at Lisbon, since July 1949 near Kindred, and since September 1929 at West Fargo. Since 1949, when Lake Ashtabula was created by completion of Baldhill Dam (13 miles upstream from Valley City), the flow of the river below the dam has been regulated by releases from the lake. Although during extended periods of little or no overland runoff the flow of the river is greater than it was before the dam was built—regulation of the flow does not diminish radically the value of the discharge data for comparative purposes.
- Because a surface-water divide and a groundwater drainage divide are near the Sheyenne River along the western edge of the delta, only a relatively small amount of groundwater drains westward to the river.
- A significant part of the increase in the discharge of Sheyenne River along the Delta is due to inflow from short tributaries which head on the Sheyenne Delta and whose base flow consists wholly of groundwater discharge from the deltaic deposits. Several tributaries extend back into the deltaic deposits from both sides of the Sheyenne River valley . The largest of these enters the valley from the south a short distance east of the west boundary of Richland County. Five measurements of the discharge at the mouth of this tributary during the period September 13 to November 20, 1963 averaged 2.2 cfs.
- the eastern stretch of the Sheyenne River through the Delta is bordered mainly by silt and fine sand that yield only small amounts of groundwater. Also considerable groundwater is diverted eastward or northeastward toward the edges of the scarp rather than into the Sheyenne River valley. The last 5.5 miles before Kindred, the river gains 1.6 cfs. Probably most inflow is derived from sand (at least 12 feet thick in places) along the delta scarp.
- The Sheyenne River lost 3.4 cfs beyond the Delta.

Shaver, R., June 9, 1998. North Dakota State Water Commission Office Memo to David Sprycznatyk, State Engineer, through Milton O. Lindvig, Director, Water Appropriations Division—Conditional Water Permit Application #5188, 31 p.

Summary

- On November 24, 1997, Ransom-Sargent Water Users, Inc. (Don Smith) submitted a conditional water permit application to the State Engineer to divert 5550 acre-feet of groundwater annually from points of diversion located in the W1/2 of S. 11, T 134N, R 54W at a maximum pumping rate of 1,300 gpm. The diversion is for municipal-rural-domestic use.

- At a hearing on February 10, 1998, a letter from Allyn J. Sapa of the US Fish and Wildlife Service was submitted that expressed concern over potential adverse impacts on the western fringed orchid (*Platanthera praeclara*) as a result of the proposed appropriation. A letter from Steve Williams of the US Forest Service was also submitted that expressed concern over potential impacts on the orchid and plant productivity in the nearby Sheyenne National Grasslands. A letter from Richard D. Nelson of the US Bureau of Reclamation requested that the State Engineer perform an analysis to delineate the maximum area of drawdown influence from the proposed pumping and the effects on groundwater seeps.
- Conceptual Model of the Sheyenne Delta aquifer
    1. Sheyenne Delta occupies about 750 square miles in Richland, Cass, Ransom, and Sargent counties (Armstrong, 1982).
    2. Near-surface sediments of the delta grade from very coarse to coarse sands in southeastern Sargent County to very fine silty sands to the north in Cass County and to the east in Richland County (Baker, 1967).
    3. Based on 108 test holes, the delta deposits range in thickness from 49 to 140 feet and averaged 97 feet (Downey and Paulson, 1974).
    4. In the Sheyenne River valley, the delta deposits have been removed by erosion and replaced by fine-grained alluvial deposits consisting of fine sand, silt, and clay beds (Armstrong, 1982).
    5. The base of the Sheyenne Delta is underlain by Lake Agassiz clay deposits and/or till.
    6. Base on a textural prerequisite greater than or equal to fine sand, the Sheyenne Delta aquifer occupies an area of about 400 square miles (Baker 1967).
    7. The Sheyenne Delta aquifer, for the most part, is unconfined.
    8. Recharge to the aquifer is primarily by relatively direct infiltration of precipitation and snowmelt. The land surface over the aquifer area is hummocky because of sand dunes and blowouts. The hummocky topography is an important control on both recharge and discharge processes.
    9. To a great extent, the recharge to the Sheyenne Delta aquifer can be characterized as depression focussed (Lissey, 1968). During the winter, a frost zone develops at or near the water table. Snow accumulates in depressions and on adjacent topographic-high areas. In the spring, snow melts before the frost zone dissipates. Snowmelt originating in the upland areas accumulates in depressions from surface runoff because of the inability to infiltrate through the frost zone. Ponded water in depressions infiltrates downward to the saturated zone after the frost zone dissipates.
    10. Recharge to the Sheyenne Delta aquifer takes place primarily during the spring. During most summer months, recharge to the aquifer is minor because potential evapotranspiration exceeds precipitation. Summer precipitation events generally are not large enough to overcome soil-moisture deficits and generate recharge. Occasionally, during the fall precipitation exceeds both evapotranspiration and soil-moisture deficits and recharge takes place. Even when recharge does not occur

during the fall, soil-moisture deficits generally are reduced, significantly affecting the magnitude of the following spring recharge event.

11. Depth to the water table is generally less than 8 feet. The capillary fringe of water table and root zone are coupled. As a result, natural discharge from the Sheyenne Delta aquifer is due, in large part, to evapotranspiration. Armstrong (1982) suggests in a year with normal precipitation, between 14 and 50 percent of precipitation that infiltrates to the aquifer as recharge eventually discharges to the Sheyenne River. Thus, about 40 to 86 percent of natural discharge from the Sheyenne Delta aquifer is due to evapotranspiration.
12. Within about 2 to 3 miles of the Sheyenne River in northern Ransom and Richland counties, the hydraulic gradient of the aquifer is about 20 to 60 feet per mile (0.0038 to 0.0114). In these areas, depths to water table commonly are greater than 8 feet and the capillary fringe of the water table and root zone are uncoupled. At distances greater than about 2 to 5 miles from the Sheyenne River, regional gradients become low and local gradients, which are toward individual low areas where evapotranspiration is greatest, mask regional trends.
13. The lake Agassiz clay deposits and till both function as aquitards (Downey and Paulson, 1974).
14. In the central part of the grassland (away from the Sheyenne River) the hydrogeologic setting is conducive to the development of numerous local flow systems (cells) in which underflow may be insignificant (rww—what proof of this???). Within each local flow system, recharge is from relatively direct infiltration of precipitation and local runoff (snow melt) that occurs primarily during the spring. The capillary fringe of the water table and root zone are coupled and therefore discharge primarily is from evapotranspiration that takes place during the growing season. "Thus, movement of ground water is largely vertical, and flow paths are relatively short."

! The western part of the Sheyenne Delta aquifer consists of stratified, very fine to very coarse sand and gravel deposits.

! "The observation well network in the application evaluation area is insufficient to characterize the shape and configuration of the water table on a local scale." "In unconfined aquifers, the configuration of the water table is a subdued replica of the land-surface topography." (This may not be right on a local scale at some times of the year—rww).

! Specific capacity tests were conducted by drilling contractors on 23 irrigation wells located in the application evaluation area (test duration ranged from 1 to 100 hours). Transmissivity was estimated using the method of Walton (1970). Estimated transmissivities ranged from 1,700 ft**2/day to about 12,000 ft**2/day, with a mean of 5,400 ft**2/day.

! William M. Schuh, Hydrologist Manger, NDSWC summarized storativity calculations for Hecla, Hamar, and Ulen soils (5 sites) in the Oakes aquifer study area in Dickey-Sargent counties (December 31, 1990 memo). Specific yield was calculated from total porosity, laboratory wetted porosity, and fielded wetted porosity. Results of study indicate little difference in specific yield between the zone of pedogenesis and the underlying coarse parent materials. Mean values of specific yield by layer were close to 0.25. Based on this, specific yield for Sheyenne Delta aquifer is 0.25 in the study area.

! Water levels remain relatively stable during the winter when recharge does not occur and evapotranspiration is greatly reduced.

! Discharge to the Sheyenne River is negligible along the western flank of the aquifer. A “20- to 40-foot difference in water-level elevations between the westernmost irrigation wells and the Sheyenne River” “indicates a poor hydraulic connection between the aquifer and the river in this area.” In this area, the Sheyenne River is incised into the glacial till.

! The average annual irrigation application rate from 1977 through 1996 is 9.7 inches per acre in the western portion of the aquifer (permit application area). Compared to the mid to late 1980s, irrigation water use decreased significantly beginning in 1993, due to wetter, cooler growing seasons.

! Water-level fluctuations caused by irrigation withdrawals are masked by water-level fluctuations caused by natural variations in recharge and discharge (primarily evapotranspiration) as dictated by changing patterns of climate.

! The State Engineer allocated groundwater with a “sustainable yield” management framework for the Sheyenne Delta aquifer because the annual recharge in many years is relatively large in relation to the volume of water in storage (i.e. water is renewable). The sustainable yield in the Sheyenne Delta aquifer is equal to the long-term average volume of groundwater discharged by evapotranspiration and underflow to the Sheyenne River. “Thus, as water is pumped from the aquifer the volume of water discharged by evapotranspiration and to the Sheyenne River will be diminished. Diminishment of groundwater evapotranspiration requires the decoupling of the plant root zone from the capillary fringe of the water table.

! The Sheyenne Natural Grasslands occupy about 110 square miles in the central part of the Sheyenne Delta aquifer (about 28 percent of the aquifer), from which groundwater withdrawals (pumping) will not likely occur.

! The State Engineer has approved an annual appropriation of 19,123.9 acre-feet from the Sheyenne Delta aquifer. This appropriated volume is 15 percent of the average annual recharge of groundwater in the practical development area of the delta.

! Allocations of appropriation are not made using digital groundwater flow models. Instead, an on-going assessment of aquifer response as related to a specific amount of groundwater development is used. Assessment of aquifer response is accomplished by water-level, water-quality, and water-use monitoring, coupled with an evaluation of climate data, aquifer properties and boundary conditions.

! “Federal agencies must ensure that nay action they authorize, fund, or carry out is not likely to jeopardize the listed (endangered or threatened) species or its critical habitat. If a federal agency determines that any such proposed action may adversely affect the listed species or its critical habitat, the agency must engage in formal consultation with the listing agency (in this case, the FWS).”

! During dry, warm climate periods the root zone and capillary fringe of the water table can become uncoupled.

! A conservative "worse-case" are of influence for a pumping well and associated drawdown distribution would result over a seven-year pumping period with no aquifer recharge. ("Note that even during the dry periods of the 1930s and 1950s, annual recharge rates of between 1 and 4 inches occurred).
! Recommended the appropriation as long as the right of prior appropriators will not be unduly affect; the proposed means of diversion or construction are adequate; the proposed use of water is beneficial; and the proposed appropriation is in the public interest.

Citations in Summary

Armstrong, C.A., 1982. Ground-water resources of Ransom and Sargent Counties, North Dakota: North Dakota Geological Survey Bulletin 69—Part III and North Dakota State Water Commission County Ground-Water Studies 31—Part III, 51 p.

Baker, C.H., Jr., 1967. Geology and ground water resources of Richland County, Part 1, Geology: North Dakota Geological Survey Bulletin 46 and North Dakota State Water Commission County Ground Water Studies 7, 45 p.

Downey, J.S. and Q.F. Paulson, 1974. Predictive modeling of effects of the planned Kindred Lake on ground-water levels and discharge, southeastern North Dakota: USGS Water-Resources Investigations 30-74, 22 p.

Lissey, A., 1968. Surficial mapping of ground-water flow systems with application to the Oak River basin, Manitoba: University of Saskatchewan, Ph.D. Thesis, 105 p.

Walton, W.C., 1970. *Groundwater Resource Evaluation*: McGraw-Hill Book Co., New York, NY, 664 p.

Cowdery, T.K. and K. Goff, 1994. Nitrogen concentrations near the water table of the Sheyenne Delta aquifer beneath cropland areas, Ransom and Richland Counties, North Dakota: Proceedings of the North Dakota Water Quality Symposium, Fargo, North Dakota, March 30-31, 1994, North Dakota State University Extension Service, p. 89-102.

Summary

! Purpose: land-use study to examine the human activities and natural factors affecting the quality of shallow (within 3 meters of land surface) groundwater underlying agricultural areas on the glacial, near-shore deltaic-facies deposits of the Sheyenne Delta. The Sheyenne Delta was selected for this study because it is a surficial aquifer and is susceptible to contamination from the land surface.
! Homogeneous land use patterns and local groundwater discharge to the Sheyenne River simplify groundwater constituent sources and make the Sheyenne Delta an excellent land-

use study site. Cattle grazing is the main use of public lands (Sheyenne National Grassland). On private land, land uses are crop production (corn and sunflowers, most of which are irrigated from the surficial aquifer with lesser amounts of soybeans, small grains, cattle forage, and potatoes) and cattle grazing.

! Paper is a review of both the 1993 nitrate-nitrogen data collected by NAWQA study and historical nitrate-nitrogen data. Purpose of study is to (1) describe nitrate concentrations near the water table beneath cropland areas after the early part of the 1993 growing season (2) relate nitrate concentration to spacial changes in land use and geology; groundwater recharge and depth to water table; and precipitation and (3) to suggest explanations for these relations.
! Samples were collected from 29 randomly selected wells during July and August 1993. Seven existing and 22 newly constructed wells form the network sampled for this study. The seven existing wells were installed by the NDSWC or the USGS during 1963 or 1972.
! Rainfall on the Delta during the 1993 growing season was 166 percent of average for last 31 years.
! Historical nitrate concentrations come from 70 samples by the NDSWC and 3 by USGS. These data were grouped into (1) High Nitrate (> 0.68 mg/L); (2) Medium Nitrate (0.23-0.68 mg/L) and (3) Low Nitrate (<0.23 mg/L)
! Samples with high to medium concentrations cluster on the west (beach) side of the delta, south and east of the Sheyenne River and west of the Sheyenne National Grassland.
! Progradation of the delta into a water body resulted in a general trend of increasing grain size in both the upward and beachward directions. Therefore the Delta aquifer should generally be hydraulically less conductive toward the east-northeast—this trend is documented by Downey and Paulson (1974) who also noted that the entire delta thins to the west as the Lake Agassiz basin approaches the surface.
! Shallow, high-production irrigation wells and crops such as corn and potatoes (that thrive in coarser-grained irrigated soils) are found most commonly on the western part of the delta. The deltaic deposits are also most homogeneous in this area.
! Because nitrogen application rates are greatest on potatoes and corn corps, it is reasonable to expect that the shallow ground water in the western part of the delta has the highest concentrations of nitrate in the study area. Nitrates may also be concentrated by pumping high-nitrate groundwater for irrigation.
! As water table rises, the time required for infiltrating water to reach the water table (lag time) decreases. This lag time increases in December when water table depth increases.
! Microbial denitrification in groundwater is not a likely mechanism for lower nitrate concentrations in wet years. DOC concentrations are too low.

Downey, J.S. and Q.F. Paulson, 1974. Predictive modeling of effects of the planned Kindred Lake on ground-water levels and discharge, southeastern North Dakota: USGS Water-Resources Investigations 30-74, 22 p.

Abstract

A digital model was used to describe a ground-water system in glacial deltaic deposits near Kindred, North Dakota, and to predict the effects of a planned lake on ground-water levels and ground-water discharge. A digital computer was used to solve the finite-difference equations for ground-water flow.

The model analysis delineated an area of about 140 square miles that would be affected by rising water levels as a result of the lake. The rise of water levels depends on time and hydraulic properties of the aquifer. The maximum projected rise in water levels should occur in about 50 years. Evapotranspiration from the water table is presently near maximum and therefore the projected water-level rise will not be controlled by evapotranspiration. Existing artificial drains will be effective in limiting the extent of water-level rise.

Summary

! Study evaluates a proposal by the US Army Corps of Engineers to build a damn on the Sheyenne River 5 miles southeast of Kindred, forming a lake in the Sheyenne River valley with normal pool of 984 ft MSL, design pool of 1,017 ft, MSL, and Maximum pool of 1,020 ft, MSL. At normal operating pool the lake would extend westward from the dam a distance of 13 miles and would have a maximum width of about 1 miles. At the Richland-Ransom County line the lake would be confined to the river channel.

! The study was undertaken to evaluate groundwater effects due to the damn. A digital groundwater model was used to perform the evaluation.

! The Sheyenne River channel is sinuous and is incised about 15 to 25 feet below the flood plain.

! East of State Highway 18, several short tributaries, generally less than 2 miles long have been eroded from the Sheyenne River back into the delta deposits. This area is underlain by deposits containing less sand and having less infiltration capacity than areas to the west.

! Much of the surface, particularly west of State Highway 18, is covered by native grasses and ins included in the Sheyenne National Grasslands administered by the US Forest Service. Extensive growths of native trees (mainly oak and aspen) are interspersed with the grasslands. The flood plain of the Sheyenne River is forested with cottonwood, elm, ash, and basswood.

! Deposits of till and associated stratified drift underlie the entire area and are exposed in the extreme western part near Sheldon. The till is an unsorted and unstratified mixture of glacially deposited rock debris, primarily clay and silt but containing varying amounts of larger fragments, including boulders. It is rather cohesive, highly calcareous, and in the subsurface, generally olive gray. The stratified drift consists of interspersed layers of sorted and stratified materials ranging from clay to gravel and generally constitutes small percentages of the overall thickness of the deposits. They have low transmissivity and function as lower and lateral (on the west and south) confining beds in the groundwater flow system. The till is underlain by shales of Late Cretaceous age.

- Highly plastic dense clay of Lake Agassiz deposits are found at depths of about 100 feet except in the Sheyenne River valley. These clay deposits probably represent the lake-floor sediments of glacial Lake Agassiz. The thickness ranged from 6 to 24 feet and averaged 49 feet. They have a very low transmissivity and function as lower confining beds in the groundwater flow system.
- Sheyenne delta deposits underlie most of the area except in the Sheyenne River valley where they have been removed by fluvial erosion. The deposits generally form the surface materials but in many places have been modified into sand dunes by wind action. They range in thickness from 49 to 140 feet and average 97 feet. The deposits grade from predominantly sand in the southwest to predominantly silt and clay in the northeast, with a corresponding decrease in hydraulic conductivity. The sand is primarily very fine to fine grained and grades northeastward into silt and clay through a transition zone of interbedded sand and silt. The delta deposits and associated sand dunes form an aquifer of considerable extend and importance in southeastern North Dakota and comprise the major aquifer of this study.
- Deposits of interbedded sand, silt and clay with numerous small mollusk shells underlie the Sheyenne River valley and are well exposed in channel walls. In 16 widely distributed test holes, the thickness of the deposits ranged from 29 to 70 feet and averaged 51 feet. The deposits are believed to be mainly fluvial in origin but may be partly lacustrine. The sand beds seem to be more dominant in the west and the silt and clay beds in the east. The alluvial deposits form an aquifer that probably has hydraulic properties similar to those of the Sheyenne delta aquifer and for the purposes of this study are considered to be an integral part of that aquifer.
- Transmissivities are largest in the sand facies of the delta deposits (@ 1,400 ft**2/d) and smallest in the silt-clay facies (200 ft**2/day).
- Only one pumping test produced a specific yield value that was believed to be valid (17%) - the others were much too low because of incomplete drainage.
- There is very little surface runoff, except in the steep slopes adjacent to either side of the Sheyenne river, its tributaries, and along the delta scarp.
- Water that infiltrates the soil must first satisfy field moisture requirements. The excess percolates downward to the saturated zone in which the water moves laterally toward areas of discharge long the river and delta front, which are at low elevations. The hydraulic gradients as determined from water levels ranged from 5 ft/mile (0.00094) to 100 feet per mile (0.019). The steeper gradients occur in the bluffs adjacent to the Sheyenne River valley in the northeastern part of the area.
- The major areas of groundwater discharge are in the Sheyenne River and its tributaries, the Sheyenne delta scarp, several manmade drains on the upland surface of the delta, and where the water table is near land surface, by evapotranspiration.
- Depth to the water table is greatest in early March, just prior to spring thaw (Baker and Paulson, 1967) and least in early April, just after spring thaw. In most of the area the maximum water-level depths are between 5 and 10 feet below land surface and the minimum depths are 2 to 5 feet.

- There is evidence of "ridges" of high groundwater levels bordering both sides of the valley. These ridges appear to be related lithologic changes in the aquifer and residuals from previous periods of recharge.
- The Sheyenne River winds its way eastward through the delta for a distance of about 52 river miles, effectively dividing the aquifer into north and south units. Previous work (Paulson, 1964) had indicated a marked increase in river discharge eastward through most of the aquifer as a result of groundwater inflow. The discharge measurements by Paulson (1964) were limited to the mainstem and did not include tributaries directly.
- Low-flow stream measurements were made during this investigation - most in tributaries. The measurements were made in May and August 1972. The measurements indicated an increase in river discharge of 109 cfs and 29.4 cfs respectively. The large difference between the two discharge increases is attributed mainly to evaporation, which normally is low in May but near maximum in August. Some of the difference is attributed to steeper hydraulic gradients in May, resulting from recharging spring rains and snowmelt, with consequently higher rates of groundwater movement.
- Of the 109 cfs increase in discharge measured in May 1972, 17.4 cfs was measured in the tributaries. Of the 29.4 cfs increase in August, 7.6 cfs was in the tributaries. These data indicate that about 84 percent of the discharge measured in May and about 73 percent measured in August was received as seepage inflow through the channel of the Sheyenne River. Furthermore, measurements were made at several points along the lengths of the tributaries and the data showed a fairly uniform increase in discharge, as would be expected in a normal groundwater discharge pattern.
- Flow model was Pinder and Trescott, slightly modified. Single layer, 33 rows and 50 columns with constant cell dimensions of 2,000 feet.
- Average K for each cell ranged form 0.1 ft/d to 30 ft/d. Specific yield values were set at 0.2 except when analyzing steady-state conditions.
- Several natural and manmade streams, including the Sheyenne River and planned lake were modeled as constant head boundaries.
- A potential evaporation rate of 30 inches per year was used in conjunction with several soil types to calculate evaporation. The evaluation of effects of evaporation from the water table indicates that little change in evaporation will occur with a rising water table because the present water table is so near land surface that evaporation is now occurring at the maximum rate possible fro the existing climatic conditions (note: this assumption was made probably because they did not have the tools to handle variable evapotranspiration terms in the model).
- The model has the following assumptions:
    1. Sheyenne delta aquifer is an extensive groundwater body with boundaries generally beyond the effects of the planned lake.
    2. The geologic materials underlying the aquifer form a relatively impervious barrier to the flow of water.
    3. The shoreline of the lake will form an aquifer boundary along with the change in head equal to the difference between the present water table and the planned lake surface.

4. Perennial streams, springs, and drains, are in hydraulic connection with the groundwater system.
5. Recharge and discharge from the groundwater system are equal.
6. At any given point within the aquifer the vertical flow component is very small in comparison to the horizontal component.

! Model calibration was obtained by comparing the output from the various simulation with the mean groundwater level for the period September 1972 through August 1973. Recharge to the model system was adjusted so that the calculated water levels from the simulation were in close agreement with the mean water levels. Calculated discharge from the model to the Sheyenne River corresponded well with the 14-day mean flow for that part of the Sheyenne River including included in the modeled area. Model calibration was directed towards having the model reproduce, as close as possible, the mean water levels.

! Results of Study:
1. Water level and streamflow data indicate that the Sheyenne River in the reaches of the planned Kindred lake is in hydraulic connection with aquifers in the Sheyenne delta deposits and alluvial deposits in the Sheyenne River valley.
2. The lake will inundate most of the aquifer in the alluvial deposits and will cause groundwater levels to rise 1 foot or more in the Sheyenne delta aquifer for a distance of as much as about 4 miles from the lake shore.
3. Evapotranspiration from the aquifer is presently near the maximum potential evaporation rate for the area and projected rises in water levels probably will not cause an increase in evapotranspiration.
4. Considerable time will be required for the rise in water levels to occur several miles back from the lake. The maximum projected rise in water levels should occur about 50 years after filling of Kindred Lake.
5. The streams and manmade drains will limit the extent of water-level rise
6. The planned lake will cause only slight increases in groundwater discharge from springs and seeps. Most of the increase will be east of the dam and should not exceed 1 cfs.

Armstrong, C.A., 1981. Supplement to: Predictive modeling of effects of the planned Kindred Lake on ground-water levels and discharge, southeastern North Dakota: USGS Open-File Report 81-646, 15 p.

Abstract

A digital model was used to describe a ground-water system in glacial deltaic deposits near Kindred, North Dakota, and to predict the effects on ground-water levels of a planned lake at 950-, 960-, 970-, 984-, and 995-foot stages. This model is a supplement to an earlier model of the ground-water system for a planned lake at the 984-foot level.

The model analysis indicates that only the area within about 2 miles of the present Sheyenne River would be affected by rising water levels as a result of a lake stage at 995 feet. The rise of water levels depends on time and hydraulic properties of the aquifer. The maximum projected rise in water levels is expected to occur in about 50 to 100 years. Evapotranspiration and existing drains will be effective in limiting the extent of water-level rise.
Consequently, the area affected by rising water levels at each lake stage will be much smaller than that shown by the earlier model at the 984-foot stage.

Summary

- The study was initiated to supplement Downey and Paulson (1974) in response to the Corps of Engineers request for evaluating the effects of the planned Kindred Lake on ground-water levels. The lake levels include elevations above and below the original 984-foot level.
- The area receives about 20 inches of precipitation annually (1972 through 1977) of which about three fourths occurs during the May through October growing season. Somewhat more than 82 percent of the annual evaporation of about 30 inches also occurs during the same period.
- Data collected between 1972 and 1977 indicate that water levels throughout the delta rise during cool periods when evapotranspiration rates are small and recharge (from precipitation and snow melt) rates are considerably larger than the yearly average rate. These conditions generally occur every spring and apparently on occasions when the weather is cooler than usual and precipitation is larger than normal, can extend into summer.
- Modifications to model of Downey and Paulson (1974):
    1. Node spacing was changed from 2,000 ft on a side to 500 ft on a side or 500 x 1000 ft. Node spacing in less critical areas was changed to as much as 4,000 ft wide and as much as 7,900 feet long. The change in node size necessitated expanding the size of the model. The lake stages of 950, 960, 970, 984, and 995 ft were simulated by using a 71 by 98 node model.
    2. The model was terminated at a groundwater divide north of the Sheyenne River and in an area with an almost flat groundwater gradient south of the river. About one-half of the southern boundary is also along a groundwater divide. These boundaries are nearly the same as those used by Downey and Paulson (1974). The western boundary, however, was shortened to the node that includes the Sheyenne River at an altitude of 995 feet.
    3. New land surface elevations at each node were determined using 5-ft contour maps. In some areas, elevation variations of as much as 50 ft existed within a node spacing and an elevation near the mean was used.
    4. Changes in node spacing required new hydraulic conductivities at each node but the changes were made with the values shown by Downey and Paulson (1974, pl. 3).
    5. Tributary drains to the Sheyenne River were modeled as partially penetrating streams instead of constant-head nodes as in the original model.

- Soil developed on the aquifer is porous and permeable. Thompson and Sweeney (1971) estimated vertical permeability equivalent to infiltration rates of 2 to 6.3 inches per hour in soils similar to those in the delta. These rates are sufficiently high to preclude most runoff except when the ground is frozen, during extremely intense precipitation periods, or when the water table is very close to the land surface.
- Through experimentation, combinations of recharge and evapotranspiration rates were found that do not exceed empirical evaluations of the aquifer and soil characteristics. These combinations were used in calibrating the model. The range of values for areal recharge was between 20 and 40 percent of the total annual precipitation of 20 inches. The use of values of less than 20 percent provided insufficient recharge to compensate for flow to the Sheyenne River. Values in excess of 40 percent produced unrealistic simulated water levels.
- Downey and Paulson (1974) considered evapotranspiration to be operating at near maximum potential rates in most of the area and therefore, did not include a function of this process in their model. This modeler did not agree with this basic assumption because water levels under much of the area are too deep for maximum potential evapotranspiration to be effective. The two-dimensional model in this study allows input of only a linear evapotranspiration function with a maximum rate at land surface and a zero rate at a fixed depth. The average annual maximum potential evaporation rate in an area including the Sheyenne Delta aquifer is about 30 inches.
- Ripple, Rubin, and van Hylckama (1972) describe a technique by which homogeneous soil types such as those in the delta may be evaluated for rates of evaporation. Calculations based on this technique show that evaporation can occur at rates close to the potential rate for depths to the water table of as much as 7.2 feet depending on soil permeabilities. The potential rates and depths are in part meteorologically controlled and the maximum potential rates and depths occur only during the hotter summer months. It was necessary to vary rates and depths of effective evapotranspiration using various recharge rates to arrive at a balance between the two rates that simulated steady-state values. A range of values for maximum evapotranspiration from 25 to 35 in per year was found to be in balance with the range of recharge rates described. Maximum depths of 6 to 10 feet for the effective evapotranspiration proved to fit best with observed steady-state conditions. Other modelers, modeling settings similar to the delta in North Dakota, came up with recharge ranges of between 7 and 8.25 inches per year and effective evapotranspiration depth limits of 8 feet.
- The average depth limit of evapotranspiration in this model was set at 8 feet. Recharge was set at 7.4 inches per year, giving the best fit of simulated to measured water levels during calibration, suing the assumed values of evapotranspiration.
- Calculated discharge of about 30 cfs from the aquifer to the Sheyenne River corresponded with the low-flow measurements for the Sheyenne River in the delta.
- Results and Conclusions:
    1. Water-level and streamflow data indicate that the Sheyenne River in the reaches of the planned Kindred Lake is in hydraulic connection with aquifers in the Sheyenne delta deposits and alluvial deposits in the Sheyenne River valley.

2. The areas affected by water-level rises of 1 foot or more are larger at each succeeding higher lake stage. However, even at the 995-foot lake stage, the area affected by a rise of 1 foot is smaller than the area shown to be affected by the 984-foot stage by Downey and Paulson (1974) in the earlier model. The difference in the modeled results is due primarily to the effects of evapotranspiration and, to a lesser extent, to the greater control in the model of the natural drains due to smaller node spacing.
3. Where the lake will inundate only the Sheyenne River flood plain, ground-water levels will rise 1 foot or more in the delta aquifer only in those areas near the lake and beneath the steeply sloping valley sides. Where the lake encroaches upon the steeper sides of the valley, water-level rises of more than 1 foot will be restricted to areas where present water levels are more than 5 feet below land surface. By comparing projected water-level rises at the 995-foot stage with the present depth to water and using an effective evapotranspiration depth of 6 feet, water-level rises of more than 1 foot generally would be restricted to areas where present water levels are more than 100 feet below land surface.
4. If actual effective depth of evapotranspiration is between 6 and 10 feet and recharge is not more than 8.25 inches, water levels will not change appreciably more than 2 miles from the present river at lake stages of 995 feet or lower.
5. The tributaries and manmade drains as well as evapotranspiration will limit the extent of water-level rise.
6. Considerable time will be required for the maximum rise in water levels to occur. Within the area between the lake shore and the 1-foot rise line, the water-level rise will be progressively larger toward the lake. Based on available data, the maximum projected rise in groundwater levels at each lake stage will occur several decades after filling of Kindred Lake. Various computer simulations indicate that the maximum projected rise in groundwater levels should occur in about 50 to 100 years. The model assumes a steady-state condition has been reached when there is less than 0.01 feet rise in 30 years.

Cited References in Summary

Downey, J.S. and Q.F. Paulson, 1974. Predictive modeling of effects of the planned Kindred Lake on ground-water levels and discharge, southeastern North Dakota: USGS Water-Resources Investigations 30-74, 22 p.

Ripple, C.D., J. Rubin, and T.E.A. van Hylckama, 1972. Estimating steady-state evaporation rates from bare soils under conditions of high water table: USGS Water-Supply Paper 2019-A, 39 p.

Thompson, D.G., and M.D. Sweeney, 1971. Soil survey, LaMoure County and parts of James River valley, North Dakota: US Dept. Of Agr., Soil Cons. Serv., 119 p.

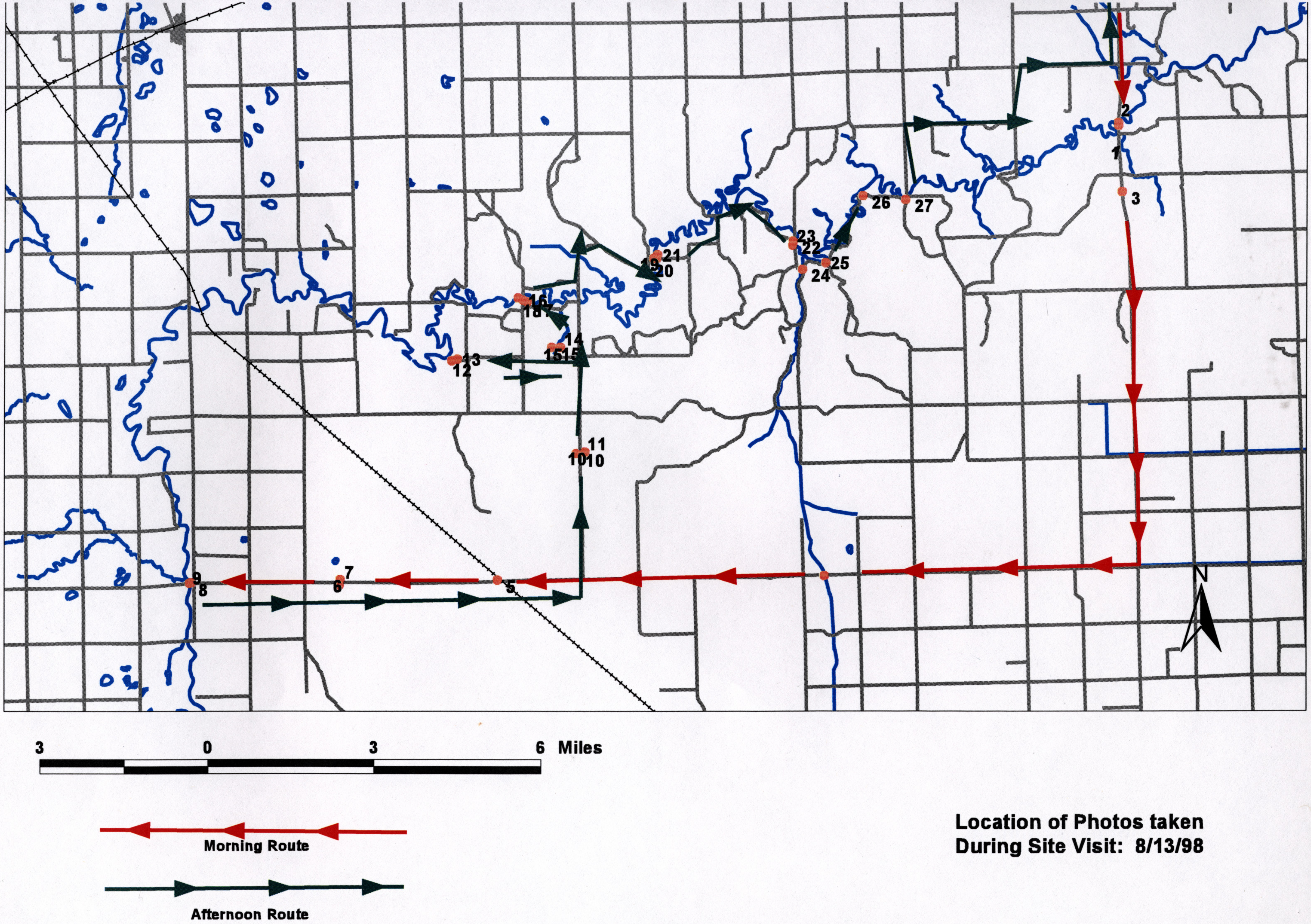
Hopkins, D.G., 1996, Hydrologic and abiotic constraints of soil genesis and natural vegetation patterns in the sandhills of North Dakota: Ph.D. thesis, North Dakota State University.

Summary

- The Sheyenne Delta aquifer is a calcium-bicarbonate type water characterized by low salinity and sodium content.
- Water from the Dakota aquifer enters the Sheyenne Delta aquifer only as flowing wells. The water is seven times more saline and nearly 40 times higher in sodium than water in the Sheyenne Delta aquifer. The Dakota aquifer is classified as a sodium-sulfate type but chloride is the dominant anion in 10 of 74 wells tested.
- Two new land use practices are occurring in the sandhills: one is management response to a natural, though undesired, example of plant succession, (leafy spurge has infested approximately 19% of the Sheyenne National Grasslands and significantly reduced rangeland productivity and stocking rates) the other a result of economic opportunities in agriculture.
- Both the USFS and private landholders in the sandhills are applying 2,4-D and picloram (Tordon) to control leafy spurge. The threat these herbicides pose to groundwater quality has not been assessed in the Sandhills.
- In the past, local irrigation has been dedicated to corn for grain or silage, but irrigated potato production has increased rapidly in the Sandhills during the last few years. Corn acreage is being converted to potato production and several large storage facilities have been erected. Ransom County acreage planted in irrigated potatoes was virtually nil in the mid-1980s and was about 1134 hectares in 1994. The number of application permits to withdraw water from the Sheyenne delta aquifer for irrigation has increased markedly.

Appendix B

Photo Log of Site Visit: August 13, 1998



Location of Photos taken
During Site Visit: 8/13/98

Summary of photos and stops on 8/13/98 field trip

Attended by Ray Wuolo (Barr Engineering Company); Bob Anfang (U.S. Army Corps of Engineers - St. Paul District), and Mark Meyers (U.S. Army Corps of Engineers - St. Paul District).

10:50 a.m.	Exit west off of US-29 onto County Road 2, heading toward Walcott.
10:55 a.m.	Turn north at Walcott on County Road 26.
11:00 a.m.	Turn west on County Road 46.
11:05 a.m.	Cross Sheyenne River at Kindred
11:10 a.m.	One mile east of County Road 18 on County Road 46. Climbed up hill believed to be northeast scarp of Sheyenne Delta. Visible seepage at base of scarp, north of road. Enter gently rolling hills. Fields are absent of cobbles and obviously sandy.
11:15 a.m.	Stop at Sheyenne River on County Road 18 (heading south). Photo 1 - Sheyenne River from bridge, looking east.

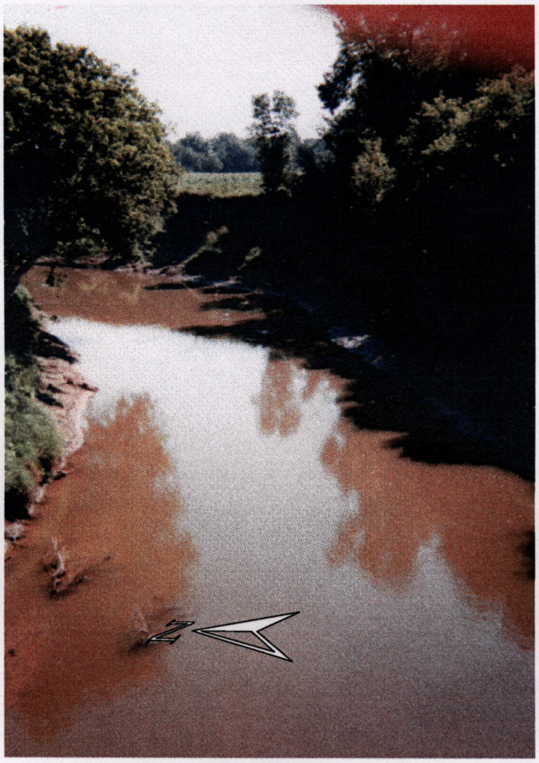


PHOTO 1

11:15 a.m. Photo 2 - sand out crop on north bank of Sheyenne River at bridge on County Road 18. Material is a fine sand with silt. No visible gravel in cutbank. No visible seepage faces but the banks approximately 2 feet above the water line along the river are obviously damp.

PHOTO 2

11:30 a.m. Heading south on County Road 18. South of Sheyenne River valley, the landscape is hummocky. Appears to be sand dunes south of valley, stabilized by vegetation.

11:32 a.m. Photo 3 - standing water approximately 1.5 miles south of Sheyenne River, east of County Road 18. Photo is looking east. Trees are in water. Cattails are present.

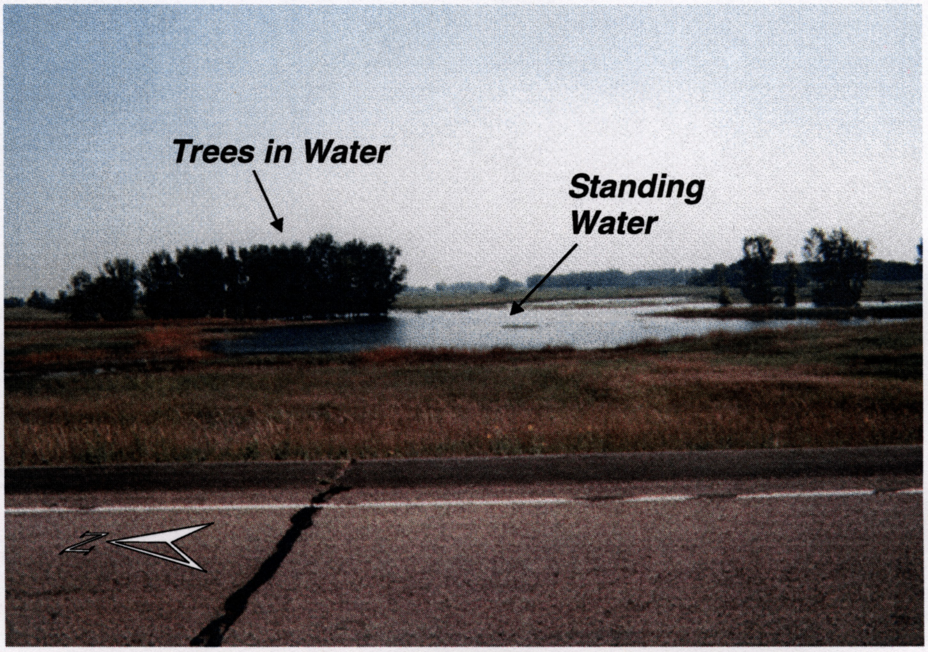


PHOTO 3

11:36 a.m.	Traveling south on County Road 18. Exposures of dune sand are prevalent. Landscape is becoming less hummocky as we go further south.
11:39 a.m.	Crossed Country Road 4. Cropping is mostly corn.
11:41 a.m.	Turned west on County Road 27, heading toward Lisbon. Center pivot irrigators on right. Stands of cottonwood are common. Terrain is nearly flat to slightly rolling.
11:46 a.m.	Entered Sheyenne National Grassland. Cropping ends.
11:50 a.m.	Photo 4 - looking south from County Road 27 at drainage ditch (trending north-south) with cows. Read grass in bank.

PHOTO 4

11:54 a.m.	Heading west on County Road 27. Darker patches of grass indicate wetter spots. Looking north, there are prominent hills (dunes) near river, about a mile north.
11:56 a.m.	Landscape becoming more hummocky. Swale and hill look to landscape. Different vegetation in low spots. Bob Anfang says that hills have less vegetation on private lands because of overgrazing.
11:58 a.m.	Bob Anfang says we're entering orchid ecology setting, where densest orchid populations are present.
11:59 a.m.	Reach railroad tracks. Photo 5 - low, wet area indicating orchid growing area. Many, many varieties of prairie plants. Dune sand is fine to medium brown, angular, well sorted, with 5 % black organic matter. Non-cohesive

PHOTO 5

12:15 p.m. Photo 6 - orchids (after flowering) in NDSU plot along south side of road. Very wet area. Photo 7 - north side of road - wet, cattails, eastern cottonwood.

PHOTO 6

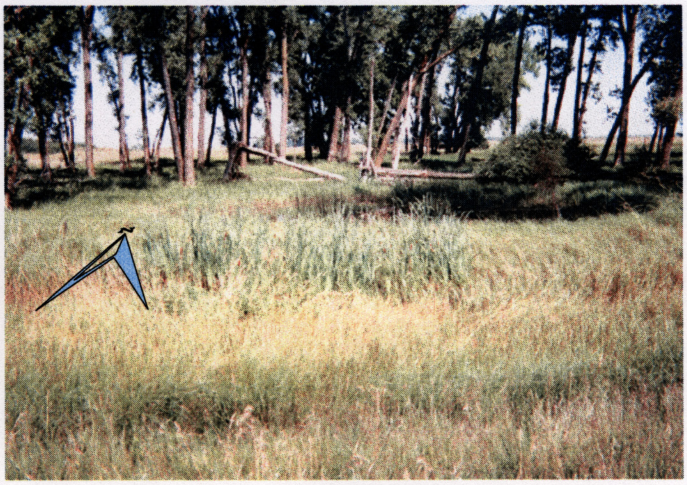


PHOTO 7

12:30 p.m. Leaving Sheyenne National Grassland on County Road 27. There is a spring on the east bank of the Sheyenne River, near the bridge. I followed it up to some cattails, about 20 feet above the river. Photo 8 - looking north from County Road 27. Photo 9 - spring locale, with cattails.

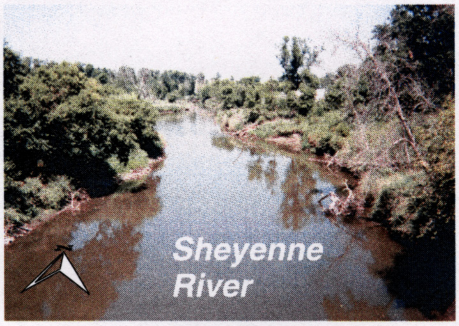


PHOTO 8

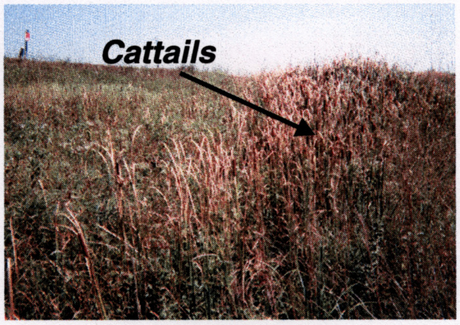


PHOTO 9

1:00 p.m. Lunch at 4G's cafe in Lisbon.

2:00 p.m. Met at U.S. Forest Service office in Lisbon with District Ranger Brian Stots and Bill Pearson of the U.S. Fish and Wildlife Service (biologist out of Bismarck). We discussed hydrology. Brian is convinced that water in swales is a surface expression of groundwater. Stots and Pearson will lead us in their vehicle on a tour.

2:15 p.m. Heading east on County Road 27, following Stots and Pearson in a U.S. Fish and Wildlife Service Vehicle.

2:35 p.m. Stop to look at orchids. Photo 10 and Photo 11 - typical hummocky orchid areas. We are on a road south of Pigeon Point.

PHOTO 10

PHOTO 11

2:54 p.m. Pigeon Point, immediately south of Sheyenne River. Observed a fen with seepage in a low drainage. Photo 12 - fen and seep.

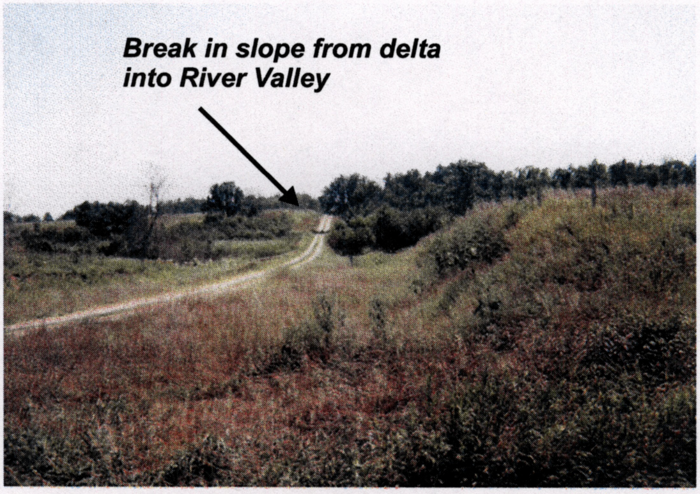


PHOTO 12

3:00 p.m. Pigeon Point fen. Photo 13 - Photo of fen flow toward River at 2-track crossing. Looks to be on a terrace. Brian Stots says this flow stays ice-free in winter. Water is clear.

PHOTO 13

3:13 p.m. Left Pigeon Point

3:35 p.m. Stop at old homestead (foundation remaining) in dune area. There is a spring in a gully. Photo 14 and Photo 15 - drainage and flow in gully. Soil is coarse sand with gravel - sand is lightly cemented, indicative of springs. Stots says fen in a hundred yards from the river.

PHOTO 14

PHOTO 15

3:50 p.m. At a drainage tributary to the River. Heavily channelized to about 1 mile from River. Large fen with cattails and bulrushes, rimmed by aspen. We are @ 200 yard from river at the fen. Fen is separate from the drainage. Grass in upland areas is very dry and crackly. Basswood in with oak near fen - westernmost extent of northern hardwood forest is in Sheyenne River valley.

4:25 p.m. Left draw area after discussing Barr's project with Stots and Pearson. Left Stots and Pearson.

4:40 p.m. Sheyenne River crossing. Photo 16 - looking at river to east. Photo 17 - cut bank on north bank. Photo 18 - looking at change in slope from floodplain to hills on north side of River. Trees are at break in slope (aspen). The floodplain is quite broad here.

PHOTO 16

PHOTO 17

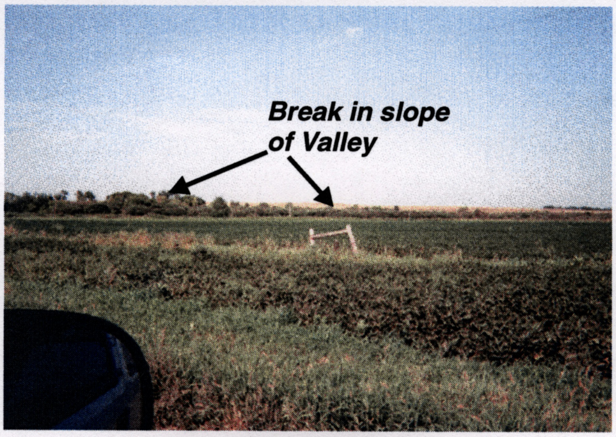


PHOTO 18

4:50 p.m. Photos 19, 20, & 21 - seepage and seepage faces on Sheyenne River banks.

PHOTO 19

PHOTO 20

PHOTO 21

5:10 p.m. Encountered 5 or 6 high-capacity wells in an east-west alignment, each about 800 to 1,000 feet apart. Marked with sign: "North Dakota Wellhead Protection Area". Big pump station at east end of well alignment.

5:15 p.m. Photos 22 & 23 - more seepage faces along river.

PHOTO 22

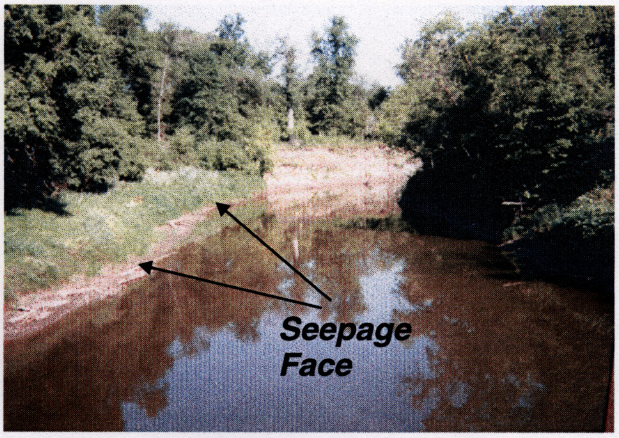


PHOTO 23

5:25 p.m Photo 24 - Iron springs creek - considerable flow in this tributary to the Sheyenne River.

PHOTO 24

5:27 p.m. Photo 25 - cutbank on Sheyenne River showing seepage about two feet above the River level.

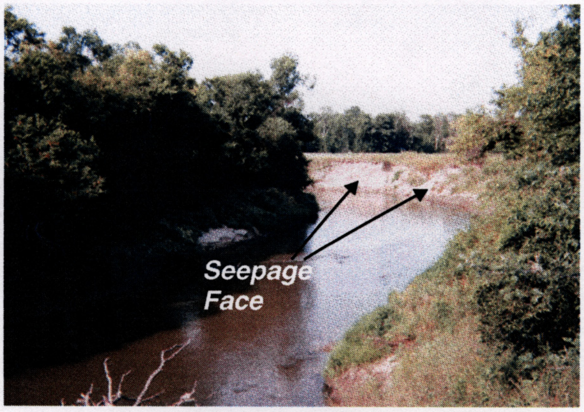


PHOTO 25

5:35 p.m. Photos 26 & 27 - Seepage along cutbank of Sheyenne River. Numerous ox-bow lakes in this area, apparently referred to as "Mirror Pools".

PHOTO 26

PHOTO 27

6:03 p.m. Scarp on County Road 46, one mile east of County Road 18. Seepage at toe of steep sand-exposed hill. Ridge runs generally northwest-southeast. Heading back to Fargo.

Appendix C

Monthly Precipitation Values (from Northern Prairie Wildlife Research Center)

USGS

Northern Prairie Wildlife Research Center

Climate of North Dakota

Figures 26, 27, and 28

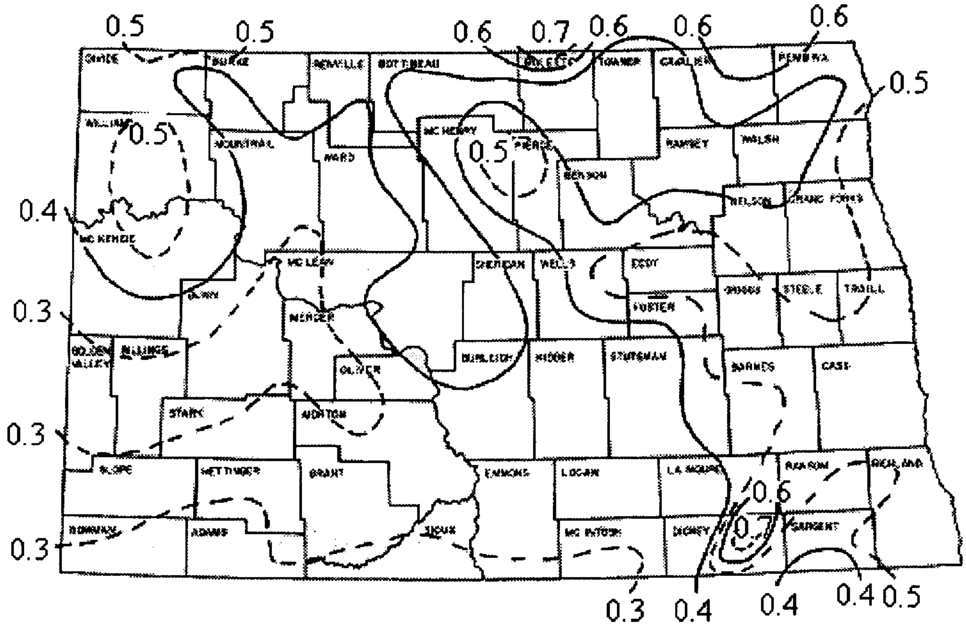


Figure 26. December Mean Precipitation in Inches.

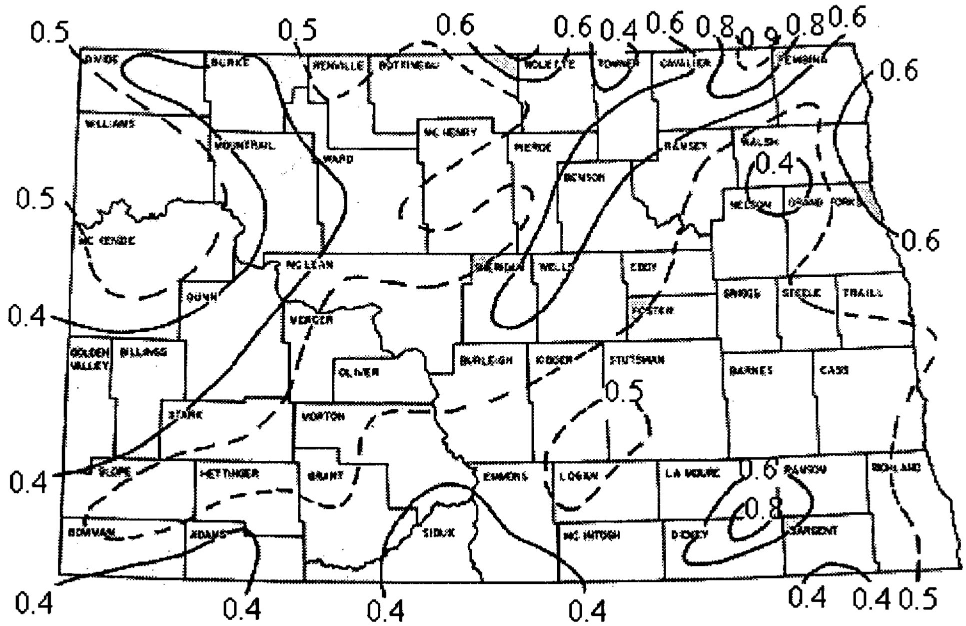


Figure 27. January Mean Precipitation in Inches.

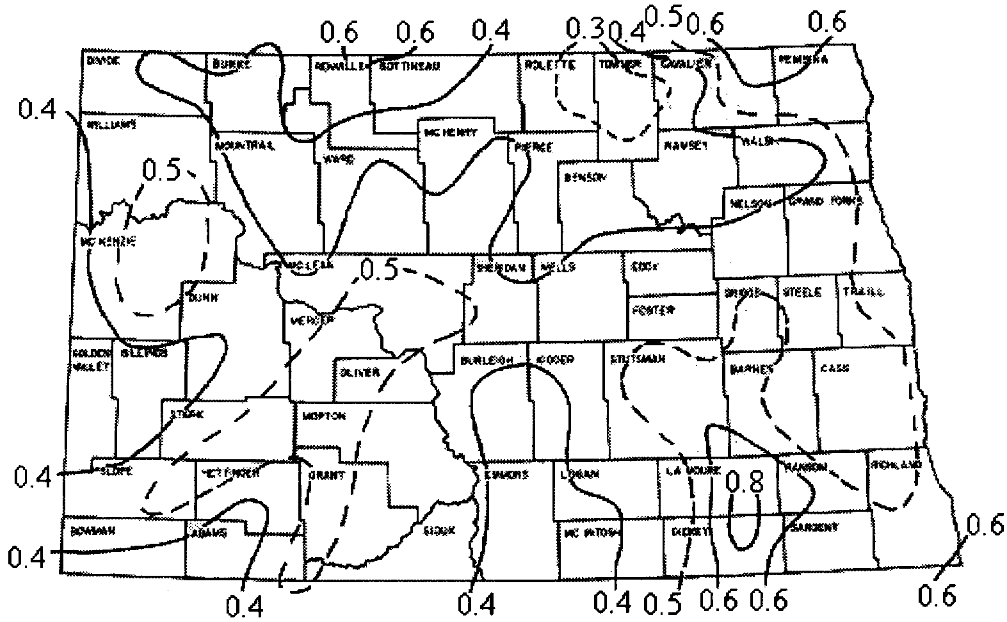


Figure 28. February Mean Precipitation in Inches.

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Next Figures -- Figures 29, 30, and 31

USGS Northern Prairie Wildlife Research Center

Climate of North Dakota

Figures 29, 30, and 31

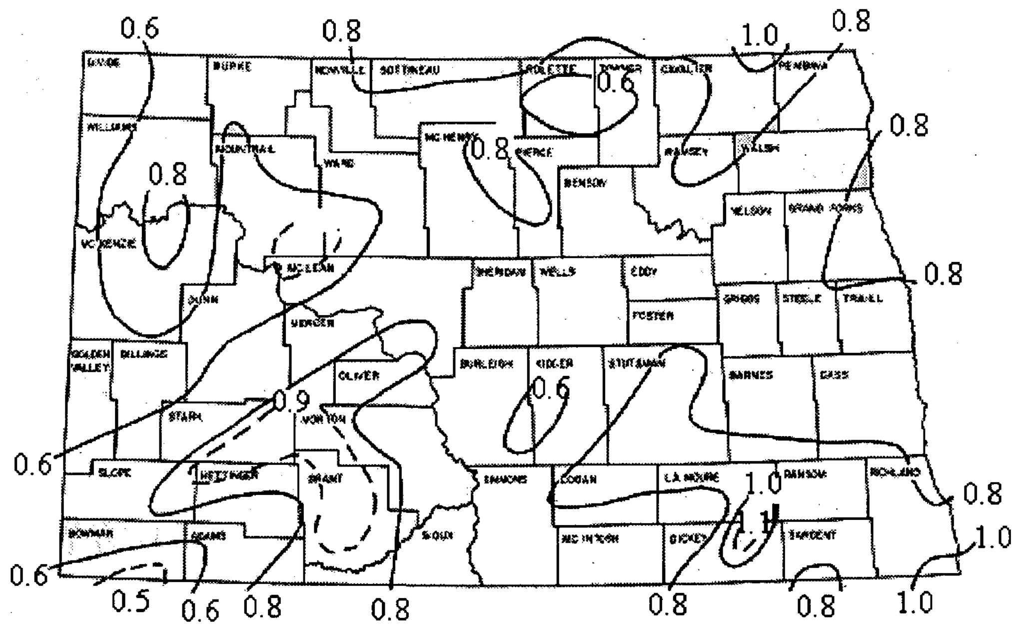

Figure 29. March Mean Precipitation in Inches.

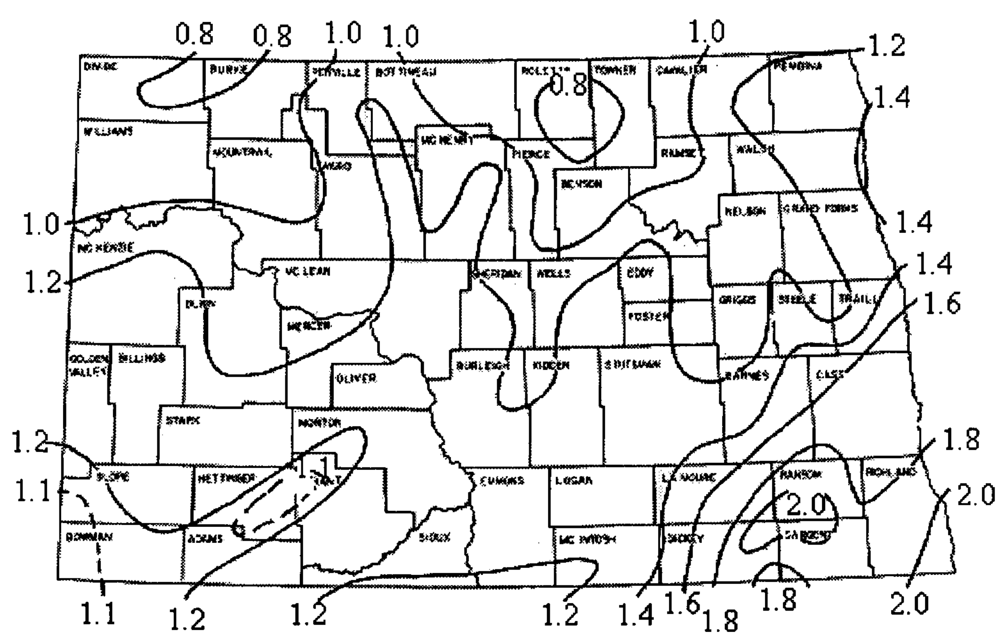

Figure 30. April Mean Precipitation in Inches.

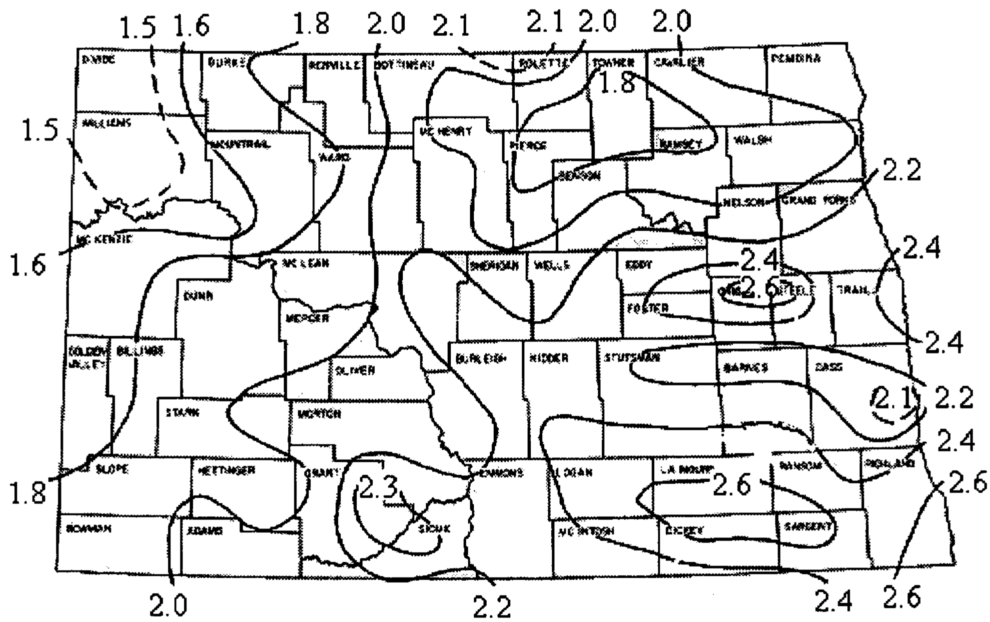

Figure 31. May Mean Precipitation in Inches.

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Next Figures -- Figures 32 and 33

USGS

Northern Prairie Wildlife Research Center

Climate of North Dakota

Figures 32 and 33

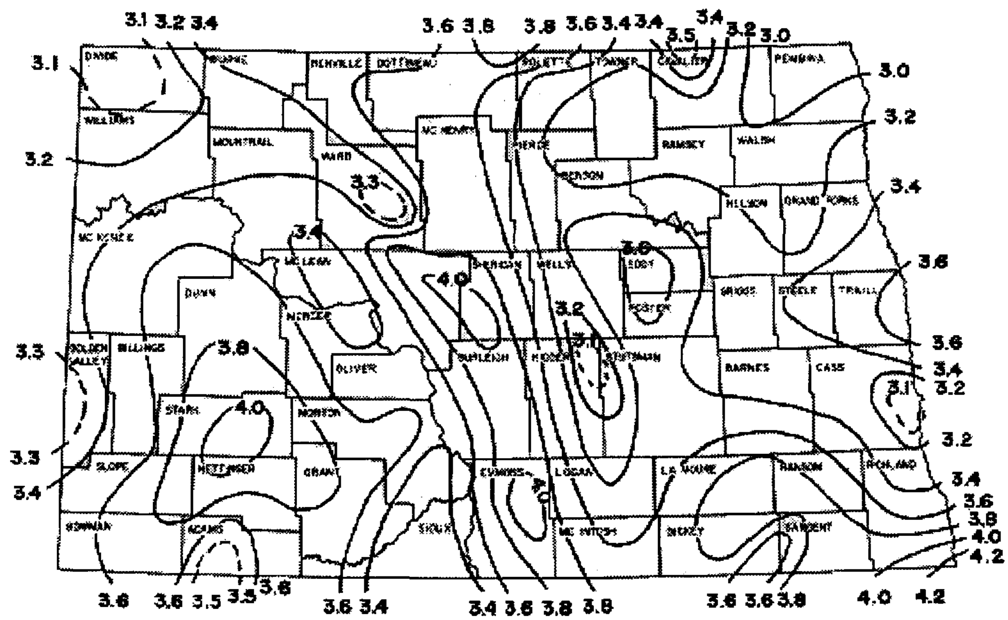

Figure 32. June Mean Precipitation in Inches.

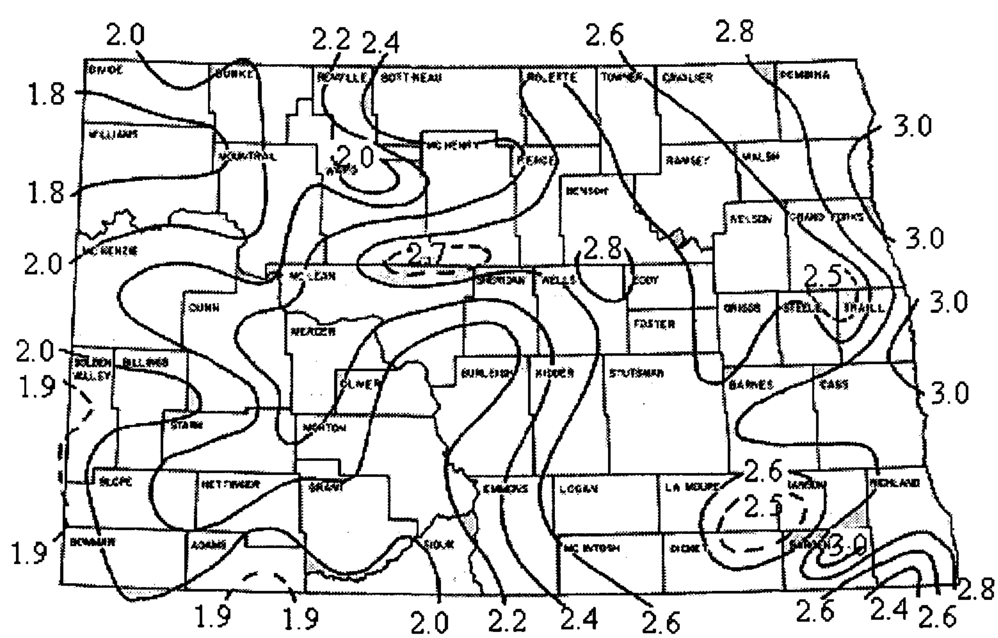

Figure 33. July Mean Precipitation in Inches.

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Next Figures -- Figures 34, 35, 36, and 37

USGS

Northern Prairie Wildlife Research Center

Climate of North Dakota

Figures 34, 35, 36, and 37

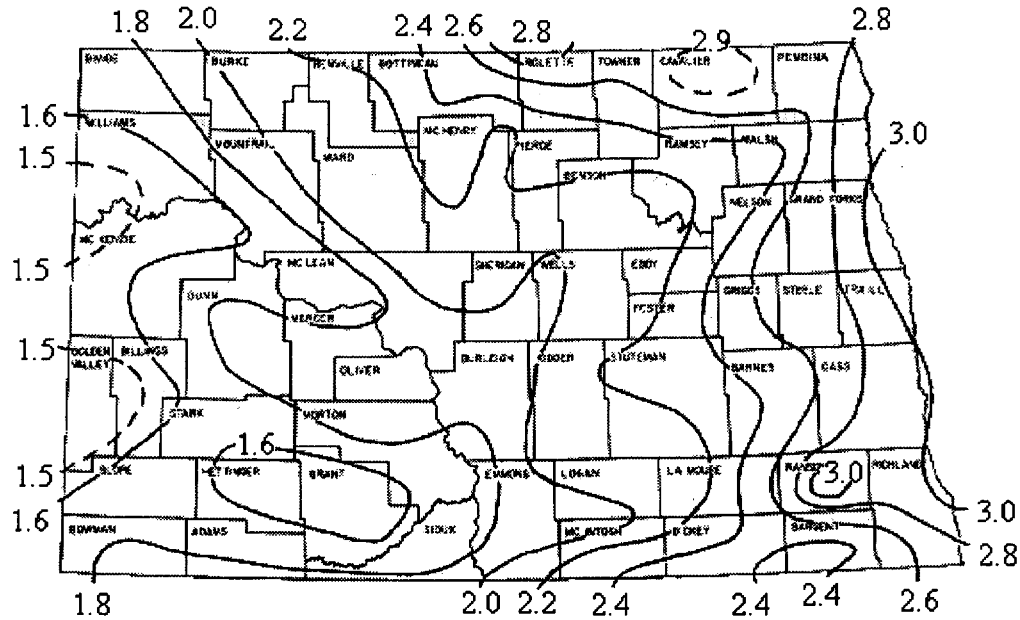

Figure 34. August Mean Precipitation in Inches.

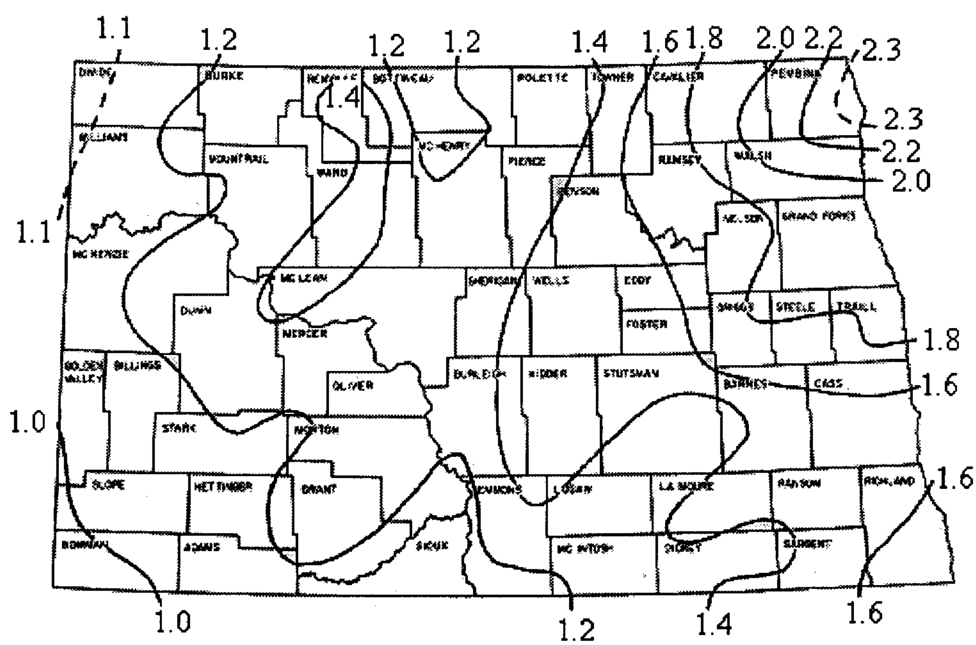

Figure 35. September Mean Precipitation in Inches.

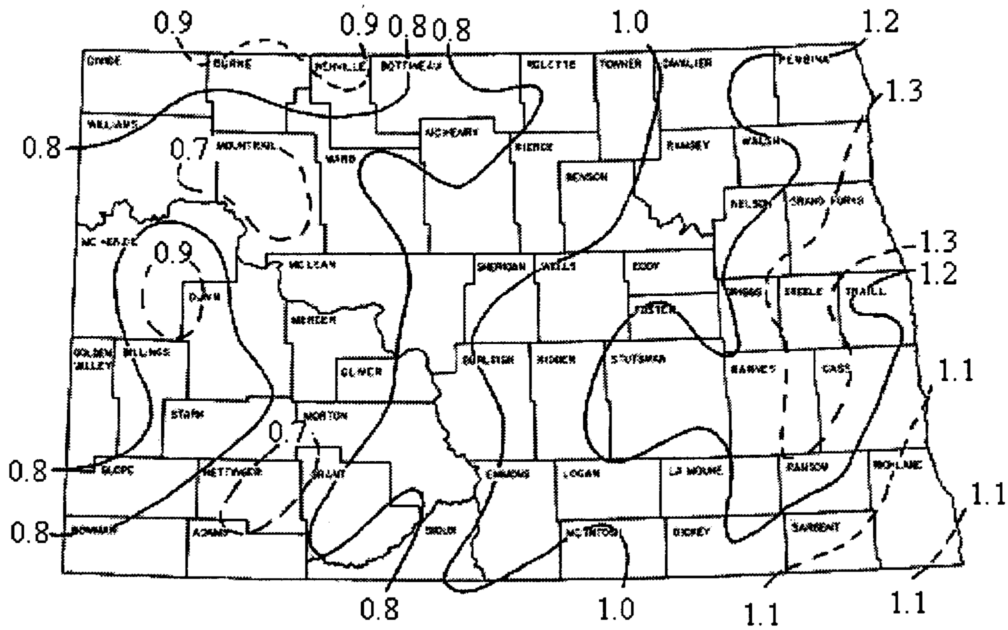

Figure 36. October Mean Precipitation in Inches.

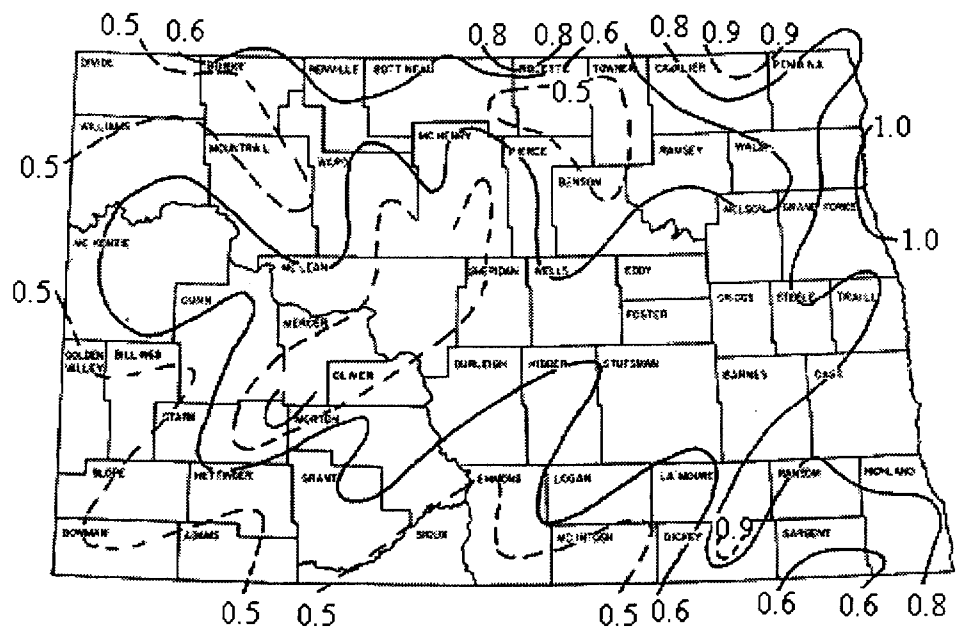

Figure 37. November Mean Precipitation in Inches.

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Appendix D

Water Year Data and Rating Tables for the Lisbon and Kindred Gages on the Sheyenne River

Water Year Data and Rating Tables for the Lisbon and Kindred Gages on the Sheyenne River

The following files were downloaded from the USGS internet site at address:

http://water.usgs.gov/cgi-bin/realsta.pl?huc=09020204

[U.S. Geological Survey] Water Resources of the United States
North Dakota

05058700 SHEYENNE RIVER AT LISBON, ND

LOCATION.--Lat 4626'49", long 9740'44", on line between secs.1 and 2, T.134 N., R.56 W., Ransom County, Hydrologic Unit 09020204, on left bank 150 ft downstream from dam at State Fish Hatchery at north edge of city of Lisbon, 3 mi upstream from Timber Coulee, and at mile 162.1.
DRAINAGE AREA.--8,190 mi2, approximately, of which about 5,700 mi2 is probably noncontributing, including 3,80 mi2 in closed basins.
WATER-DISCHARGE RECORDS
PERIOD OF RECORD.--September 1956 to current year.
REVISED RECORDS.--WSP 1728: Drainage area.
GAGE.--Water-stage recorder. Datum of gage is 1,066.46 ft above sea level.
REMARKS.--Records good except for period of estimated discharge, which are fair. Flow regulated by Lake Ashtabula (station 05057500) 108.5 mi upstream.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1996 TO SEPTEMBER 1997
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	56	61	234	e170	e220	e170	e2600	5120	465	301	266	75
2	44	67	279	e170	e220	e170	e3000	5220	502	280	233	82

3	37	78	281	e170	e210	e160	e2800	5150	625	263	158	111
4	32	91	278	e170	e210	e150	e3800	4950	1010	266	180	149
5	30	92	277	e170	e210	e150	e5200	4730	693	330	171	105
6	28	95	276	e170	e210	e150	e4800	4490	578	531	169	87
7	26	103	266	e170	e210	e140	e4200	4320	442	603	168	83
8	28	112	248	e170	e210	e150	e3800	4180	433	601	166	83
9	29	132	234	e180	e210	e150	e3400	3990	450	535	165	78
10	29	91	234	e180	e210	e140	e3000	3690	431	471	161	72
11	29	96	234	e180	e200	e140	e2600	3160	410	621	157	67
12	29	117	234	e190	e200	e140	e2300	2560	332	628	157	82
13	29	134	235	e190	e200	e140	2560	2110	290	565	155	87
14	28	141	226	e200	e200	e140	3050	1870	279	467	147	77
15	30	143	156	e200	e190	e140	3650	1790	286	362	152	81
16	32	147	84	e200	e190	e140	3920	1760	258	306	153	79
17	36	156	131	e190	e200	e140	4190	1710	234	275	81	71
18	32	152	e230	e200	e190	e140	4460	1490	218	267	93	68

19	29	149	e230	e200	e190	e150	4710	1160	215	287	108	65
20	29	156	e230	e200	e190	e160	4970	877	207	316	104	64
21	35	160	e220	e200	e180	e170	5290	848	183	312	103	62
22	40	164	e210	e200	e180	e180	5580	838	181	305	101	59
23	40	175	e200	e200	e170	e180	5650	867	182	292	90	61
24	32	203	e190	e200	e170	e160	5580	896	195	281	80	73
25	149	224	e180	e200	e170	e120	5410	960	798	275	75	77
26	135	237	e170	e190	e180	e100	5210	1020	1220	274	73	78
27	91	229	e160	e190	e180	e150	5030	1010	774	326	73	77
28	61	193	e160	e200	e180	e350	4870	987	554	381	71	80
29	64	152	e160	e210	---	e600	4840	948	396	357	70	74
30	77	162	e160	e220	---	e1000	4950	832	331	343	65	74
31	53	---	e160	e220	---	e1800	---	692	---	304	58	---
TOTAL	1419	4212	6567	5900	5480	7770	125420	74225	13172	11725	4003	2381
MEAN	45.8	140	212	190	196	251	4181	2394	439	378	129	79.4
MAX	149	237	281	220	220	1800	5650	5220	1220	628	266	149

MIN	26	61	84	170	170	100	2300	692	181	263	58	59
AC-FT	2810	8350	13030	11700	10870	15410	248800	147200	26130	23260	7940	4720

STATISTICS OF MONTHLY MEAN DATA FOR WATER YEARS 1957 - 1997, BY WATER YEAR (WY)

MEAN	66.5	77.6	74.2	68.8	86.3	334	795	357	174	170	109	68.5
MAX	716	454	290	204	413	1525	4181	2394	555	1424	1945	561
(WY)	1995	1995	1995	1995	1996	1995	1997	1997	1974	1993	1993	1994
MIN	7.66	12.2	8.69	8.15	10.7	19.8	20.3	17.5	14.8	6.07	6.54	5.25
(WY)	1957	1991	1991	1991	1991	1964	1991	1959	1961	1973	1961	1959

SUMMARY STATISTICS	FOR 1996 CALENDAR YEAR		FOR 1997 WATER YEAR		WATER YEARS 1957 - 1997	
ANNUAL TOTAL	206430		262274			
ANNUAL MEAN	564		719		198	
HIGHEST ANNUAL MEAN					719	1997
LOWEST ANNUAL MEAN					25.9	1991
HIGHEST DAILY MEAN	5050	Apr 26	5650	Apr 23	5650	Apr 23 1997
LOWEST DAILY MEAN	18	Sep 13	26	Oct 7	.00	Oct 23 1956
ANNUAL SEVEN-DAY MINIMUM	18	Sep 12	28	Oct 6	.87	Oct 1 1956
INSTANTANEOUS PEAK FLOW			5670	Apr 23	5670	Apr 23 1997

INSTANTANEOUS PEAK STAGE		a 19.29 Apr 5	a 19.29 Apr 5 1997
ANNUAL RUNOFF (AC-FT)	409500	520200	143700
10 PERCENT EXCEEDS	1190	2880	427
50 PERCENT EXCEEDS	210	190	57
90 PERCENT EXCEEDS	36	67	15

a Backwater from ice.
e Estimated.

05058700 SHEYENNE RIVER AT LISBON, ND--Continued

WATER-QUALITY RECORDS

PERIOD OF RECORD.--Water year 1956 to current year.

WATER-QUALITY DATA, WATER YEAR OCTOBER 1996 TO SEPTEMBER 1997

DATE	TIME	DIS-CHARGE, INST. CUBIC FEET PER SECOND (00061)	SPE-CIFIC CON-DUCT-ANCE (US/CM) (00095)	PH WATER WHOLE FIELD (STAND-ARD UNITS) (00400)	TEMPER-ATURE AIR (DEG C) (00020)	TEMPER-ATURE WATER (DEG C) (00010)	HARD-NESS TOTAL (MG/L AS CACO3) (00900)	ALKA-LINITY LAB (MG/L AS CACO3) (90410)	CALCIUM DIS-SOLVED (MG/L AS CA) (00915)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG) (00925)
OCT										
01...	1310	55	1100	--	12.0	11.5	--	--	--	--
NOV										
14...	1320	137	1340	--	0.0	1.0	--	--	--	--
MAR										
18...	1230	139	1350	--	-1.0	0.5	--	--	--	--
APR										
01...	1525	2580	602	--	12.0	1.0	--	--	--	--
17...	1130	4060	586	7.9	3.0	2.5	200	132	45	22
26...	1820	5230	560	--	10.0	7.5	--	--	--	--
MAY										
18...	1800	1360	784	--	12.0	14.0	--	--	--	--

DATE	SODIUM, DIS- SOLVED (MG/L AS NA) (00930)	SODIUM PERCENT (00932)	SODIUM AD- SORP- TION RATIO (00931)	POTAS- SIUM, DIS- SOLVED (MG/L AS K) (00935)	SULFATE DIS- SOLVED (MG/L AS SO4) (00945)	CHLO- RIDE, DIS- SOLVED (MG/L AS CL) (00940)	FLUO- RIDE, DIS- SOLVED (MG/L AS F) (00950)	SOLIDS, SUM OF CONSTI- TUENTS, DIS- SOLVED (MG/L) (70301)	SOLIDS, RESIDUE AT 180 DEG. C DIS- SOLVED (MG/L) (70300)	SOLIDS, DIS- SOLVED (TONS PER AC-FT) (70303)
APR										
17...	39	28	1	9.2	150	16	0.10	361	381	0.52

DATE	SOLIDS, DIS- SOLVED (TONS PER DAY) (70302)	ARSENIC DIS- SOLVED (UG/L AS AS) (01000)	IRON, DIS- SOLVED (UG/L AS FE) (01046)	LEAD, DIS- SOLVED (UG/L AS PB) (01049)	LITHIUM DIS- SOLVED (UG/L AS LI) (01130)	MANGA- NESE, DIS- SOLVED (UG/L AS MN) (01056)	MERCURY DIS- SOLVED (UG/L AS HG) (71890)	MOLYB- DENUM, DIS- SOLVED (UG/L AS MO) (01060)	SELE- NIUM, DIS- SOLVED (UG/L AS SE) (01145)	STRON- TIUM, DIS- SOLVED (UG/L AS SR) (01080)
APR										
17...	4180	1	90	<1.0	30	110	<0.1	<1.0	<1	240

[U.S. Department of Interior] [U.S. Geological Survey]

Information concerning the accuracy and appropriate uses of these data or concerning other hydrologic data may be obtained from:

<--Click here to send an automated data request.

Chief, Hydrologic Records and Information Section
U.S. Geological Survey
821 East Interstate Avenue
Bismarck, North Dakota 58501-1199
(701) 250-7404 [Fax: (701) 250-7492]
email: <harkness@usgs.gov>

If you have any questions or comments about this www site please contact:

<--Click here to send an automated comment form.

Generated by: 1997 Annual Report Table for 05058700
Mon, 24 Aug 1998 15:34:28 CDT

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1                        UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
             PAGE  1
                                                    EXPANDED RATING TABLE
      TYPE: LOG
 05058700                                           DATE PROCESSED: 01-21-1997 @ 10:55 BY JEWAGNER
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SHEYENNE RIVER AT LISBON, ND DD: 7 TYPE: 001 RATING NO: 19.0
OFFSET: 1.50 START DATE/TIME: 10-01-94 (0015)

BASED ON _______ DISCHARGE MEASUREMENTS, NOS ________, AND ________, AND IS ______ WELL DEFINED BETWEEN _____ AND ______ CFS

COMP BY _____ DATE ________ CHK. BY _____ DATE ________

DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)

GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
1.70							1.000*	1.184	1.394	1.632	2.250
1.80	1.900*	2.136	2.392	2.669	2.969	3.292	3.640	4.014	4.414	4.842	3.400
1.90	5.300*	5.853	6.449	7.089	7.775	8.510	9.297	10.14	11.03	11.99	7.700
2.00	13.00*	13.83	14.70	15.60	16.54	17.52	18.53	19.59	20.68	21.82	10.00
2.10	23.00*	24.06	25.15	26.27	27.42	28.60	29.82	31.06	32.34	33.65	12.00
2.20	35.00*	36.11	37.25	38.40	39.57	40.76	41.97	43.20	44.44	45.71	12.00
2.30	47.00*	48.23	49.47	50.73	52.00	53.29	54.60	55.93	57.27	58.63	13.00
2.40	60.00*	61.33	62.68	64.05	65.42	66.82	68.22	69.65	71.08	72.53	14.00

2.50	74.00*	75.37	76.75	78.14	79.54	80.96	82.38	83.82	85.27	86.73	14.20
2.60	88.20*	89.61	91.02	92.45	93.89	95.33	96.79	98.25	99.72	101.2	14.50
2.70	102.7*	104.1	105.6	107.1	108.5	110.0	111.5	113.0	114.5	116.0	14.80
2.80	117.5*	119.0	120.5	122.1	123.6	125.2	126.7	128.3	129.8	131.4	15.50
2.90	133.0*	134.7	136.3	138.0	139.7	141.4	143.1	144.8	146.5	148.3	17.00
3.00	150.0*	151.8	153.5	155.3	157.1	158.9	160.7	162.5	164.3	166.2	18.00
3.10	168.0*	169.8	171.5	173.3	175.1	176.9	178.7	180.5	182.3	184.2	18.00
3.20	186.0*	187.9	189.7	191.6	193.5	195.4	197.3	199.2	201.1	203.1	19.00
3.30	205.0*	206.9	208.7	210.6	212.5	214.4	216.3	218.2	220.1	222.1	19.00
3.40	224.0*	225.9	227.8	229.6	231.5	233.4	235.3	237.2	239.2	241.1	19.00
3.50	243.0*	244.9	246.8	248.6	250.5	252.4	254.3	256.2	258.2	260.1	19.00
3.60	262.0*	263.9	265.8	267.7	269.6	271.6	273.5	275.4	277.4	279.3	19.30
3.70	281.3	283.2	285.2	287.1	289.1	291.1	293.1	295.0	297.0	299.0	19.70
3.80	301.0*	302.9	304.8	306.8	308.7	310.6	312.5	314.5	316.4	318.4	19.30
3.90	320.3	322.3	324.2	326.2	328.1	330.1	332.1	334.1	336.0	338.0	19.70
4.00	340.0*	342.0	343.9	345.9	347.9	349.9	351.9	353.8	355.8	357.8	19.80

4.10	359.8	361.8	363.8	365.8	367.9	369.9	371.9	373.9	375.9	378.0	20.20
4.20	380.0*	382.0	383.9	385.9	387.9	389.9	391.9	393.9	395.9	397.9	19.90
4.30	399.9	401.9	403.9	405.9	407.9	409.9	411.9	413.9	415.9	418.0	20.10
4.40	420.0*	422.1	424.2	426.3	428.4	430.5	432.6	434.8	436.9	439.0	21.10
4.50	441.1	443.3	445.4	447.5	449.7	451.8	454.0	456.1	458.3	460.4	21.50
4.60	462.6	464.7	466.9	469.1	471.2	473.4	475.6	477.8	480.0	482.2	21.70
4.70	484.3	486.5	488.7	490.9	493.1	495.3	497.5	499.8	502.0	504.2	22.10
4.80	506.4	508.6	510.9	513.1	515.3	517.6	519.8	522.0	524.3	526.5	22.40
4.90	528.8	531.0	533.3	535.6	537.8	540.1	542.3	544.6	546.9	549.2	22.60
5.00	551.4	553.7	556.0	558.3	560.6	562.9	565.2	567.5	569.8	572.1	23.00
5.10	574.4	576.7	579.0	581.4	583.7	586.0	588.3	590.7	593.0	595.3	23.30
5.20	597.7	600.0	602.3	604.7	607.0	609.4	611.7	614.1	616.5	618.8	23.50
5.30	621.2	623.6	625.9	628.3	630.7	633.1	635.4	637.8	640.2	642.6	23.80
5.40	645.0	647.4	649.8	652.2	654.6	657.0	659.4	661.8	664.2	666.7	24.10

1 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION PAGE 2

EXPANDED RATING TABLE

TYPE: LOG

05058700 DATE PROCESSED: 01-21-1997 @ 10:55 BY JEWAGNER
SHEYENNE RIVER AT LISBON, ND DD: 7 TYPE: 001 RATING NO: 19.0
OFFSET: 1.50 START DATE/TIME: 10-01-94 (0015)

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION) .00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
5.50	669.1	671.5	673.9	676.4	678.8	681.2	683.7	686.1	688.5	691.0	24.30
5.60	693.4	695.9	698.3	700.8	703.2	705.7	708.2	710.6	713.1	715.6	24.70
5.70	718.1	720.5	723.0	725.5	728.0	730.5	733.0	735.4	737.9	740.4	24.80
5.80	742.9	745.4	748.0	750.5	753.0	755.5	758.0	760.5	763.0	765.6	25.20
5.90	768.1	770.6	773.1	775.7	778.2	780.8	783.3	785.8	788.4	790.9	25.40
6.00	793.5	796.0	798.6	801.2	803.7	806.3	808.9	811.4	814.0	816.6	25.70
6.10	819.2	821.7	824.3	826.9	829.5	832.1	834.7	837.3	839.9	842.5	25.90
6.20	845.1	847.7	850.3	852.9	855.5	858.1	860.7	863.3	866.0	868.6	26.10
6.30	871.2	873.9	876.5	879.1	881.8	884.4	887.0	889.7	892.3	895.0	26.40
6.40	897.6	900.3	902.9	905.6	908.3	910.9	913.6	916.3	918.9	921.6	26.70

6.50	924.3	926.9	929.6	932.3	935.0	937.7	940.4	943.1	945.8	948.5	26.90
6.60	951.2	953.9	956.6	959.3	962.0	964.7	967.4	970.1	972.8	975.6	27.10
6.70	978.3	981.0	983.7	986.5	989.2	991.9	994.7	997.4	1000	1003	27.70
6.80	1006	1008	1011	1014	1017	1019	1022	1025	1028	1030	27.00
6.90	1033	1036	1039	1042	1044	1047	1050	1053	1055	1058	28.00
7.00	1061	1064	1067	1069	1072	1075	1078	1081	1083	1086	28.00
7.10	1089	1092	1095	1098	1100	1103	1106	1109	1112	1115	28.00
7.20	1117	1120	1123	1126	1129	1132	1134	1137	1140	1143	29.00
7.30	1146	1149	1152	1154	1157	1160	1163	1166	1169	1172	29.00
7.40	1175	1177	1180	1183	1186	1189	1192	1195	1198	1201	29.00
7.50	1204	1206	1209	1212	1215	1218	1221	1224	1227	1230	29.00
7.60	1233	1236	1239	1241	1244	1247	1250	1253	1256	1259	29.00
7.70	1262	1265	1268	1271	1274	1277	1280	1283	1286	1289	30.00
7.80	1292	1295	1298	1301	1304	1306	1309	1312	1315	1318	29.00
7.90	1321	1324	1327	1330	1333	1336	1339	1342	1345	1348	30.00
8.00	1351	1354	1357	1360	1363	1366	1370	1373	1376	1379	31.00

8.10	1382	1385	1388	1391	1394	1397	1400	1403	1406	1409	30.00
8.20	1412	1415	1418	1421	1424	1427	1430	1433	1437	1440	31.00
8.30	1443	1446	1449	1452	1455	1458	1461	1464	1467	1470	30.00
8.40	1473	1477	1480	1483	1486	1489	1492	1495	1498	1501	31.00
8.50	1504	1508	1511	1514	1517	1520	1523	1526	1529	1533	32.00
8.60	1536	1539	1542	1545	1548	1551	1555	1558	1561	1564	31.00
8.70	1567	1570	1573	1577	1580	1583	1586	1589	1592	1596	32.00
8.80	1599	1602	1605	1608	1611	1615	1618	1621	1624	1627	32.00
8.90	1631	1634	1637	1640	1643	1647	1650	1653	1656	1659	32.00
9.00	1663	1666	1669	1672	1675	1679	1682	1685	1688	1692	32.00
9.10	1695	1698	1701	1704	1708	1711	1714	1717	1721	1724	32.00
9.20	1727	1730	1734	1737	1740	1743	1747	1750	1753	1756	33.00

1 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION PAGE 3

EXPANDED RATING TABLE

TYPE: LOG

05058700 DATE PROCESSED: 01-21-1997 @ 10:55 BY JEWAGNER

SHEYENNE RIVER AT LISBON, ND DD: 7 TYPE: 001 RATING NO: 19.0

OFFSET: 1.50 START DATE/TIME: 10-01-94 (0015)

GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
				DISCHARGE IN CUBIC FEET PER SECOND				(EXPANDED PRECISION)			
9.30	1760	1763	1766	1770	1773	1776	1779	1783	1786	1789	32.00
9.40	1792	1796	1799	1802	1806	1809	1812	1816	1819	1822	33.00
9.50	1825	1829	1832	1835	1839	1842	1845	1849	1852	1855	34.00
9.60	1859	1862	1865	1869	1872	1875	1879	1882	1885	1889	33.00
9.70	1892	1895	1899	1902	1905	1909	1912	1915	1919	1922	33.00
9.80	1925	1929	1932	1935	1939	1942	1946	1949	1952	1956	34.00
9.90	1959	1962	1966	1969	1973	1976	1979	1983	1986	1989	34.00
10.00	1993	1996	2000	2003	2006	2010	2013	2017	2020	2024	34.00
10.10	2027	2030	2034	2037	2041	2044	2047	2051	2054	2058	34.00
10.20	2061	2065	2068	2071	2075	2078	2082	2085	2089	2092	35.00
10.30	2096	2099	2102	2106	2109	2113	2116	2120	2123	2127	34.00
10.40	2130	2134	2137	2141	2144	2147	2151	2154	2158	2161	35.00

10.50	2165	2168	2172	2175	2179	2182	2186	2189	2193	2196	35.00
10.60	2200	2203	2207	2210	2214	2217	2221	2224	2228	2231	35.00
10.70	2235	2238	2242	2245	2249	2252	2256	2260	2263	2267	35.00
10.80	2270	2274	2277	2281	2284	2288	2291	2295	2298	2302	36.00
10.90	2306	2309	2313	2316	2320	2323	2327	2330	2334	2338	35.00
11.00	2341	2345	2348	2352	2355	2359	2363	2366	2370	2373	36.00
11.10	2377	2380	2384	2388	2391	2395	2398	2402	2406	2409	36.00
11.20	2413	2416	2420	2424	2427	2431	2434	2438	2442	2445	36.00
11.30	2449	2453	2456	2460	2463	2467	2471	2474	2478	2482	36.00
11.40	2485	2489	2492	2496	2500	2503	2507	2511	2514	2518	37.00
11.50	2522	2525	2529	2533	2536	2540	2544	2547	2551	2555	36.00
11.60	2558	2562	2566	2569	2573	2577	2580	2584	2588	2591	37.00
11.70	2595	2599	2602	2606	2610	2613	2617	2621	2625	2628	37.00
11.80	2632	2636	2639	2643	2647	2650	2654	2658	2662	2665	37.00
11.90	2669	2673	2676	2680	2684	2688	2691	2695	2699	2703	37.00
12.00	2706	2710	2714	2717	2721	2725	2729	2732	2736	2740	38.00

12.10	2744	2747	2751	2755	2759	2762	2766	2770	2774	2777	37.00
12.20	2781	2785	2789	2792	2796	2800	2804	2808	2811	2815	38.00
12.30	2819	2823	2826	2830	2834	2838	2842	2845	2849	2853	38.00
12.40	2857	2861	2864	2868	2872	2876	2880	2883	2887	2891	38.00
12.50	2895	2899	2902	2906	2910	2914	2918	2922	2925	2929	38.00
12.60	2933	2937	2941	2944	2948	2952	2956	2960	2964	2967	38.00
12.70	2971	2975	2979	2983	2987	2991	2994	2998	3002	3006	39.00
12.80	3010	3014	3018	3021	3025	3029	3033	3037	3041	3045	38.00
12.90	3048	3052	3056	3060	3064	3068	3072	3076	3079	3083	39.00

1 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION PAGE 4

EXPANDED RATING TABLE

TYPE: LOG

05058700 DATE PROCESSED: 01-21-1997 @ 10:55 BY JEWAGNER

SHEYENNE RIVER AT LISBON, ND DD: 7 TYPE: 001 RATING NO: 19.0

OFFSET: 1.50 START DATE/TIME: 10-01-94 (0015)

GAGE HEIGHT — DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION) — DIFF IN Q PER

(FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	TENTH FT
13.00	3087	3091	3095	3099	3103	3107	3111	3115	3118	3122	39.00
13.10	3126	3130	3134	3138	3142	3146	3150	3154	3157	3161	39.00
13.20	3165	3169	3173	3177	3181	3185	3189	3193	3197	3201	40.00
13.30	3205	3208	3212	3216	3220	3224	3228	3232	3236	3240	39.00
13.40	3244	3248	3252	3256	3260	3264	3268	3272	3276	3280	39.00
13.50	3283	3287	3291	3295	3299	3303	3307	3311	3315	3319	40.00
13.60	3323	3327	3331	3335	3339	3343	3347	3351	3355	3359	40.00
13.70	3363	3367	3371	3375	3379	3383	3387	3391	3395	3399	40.00
13.80	3403	3407	3411	3415	3419	3423	3427	3431	3435	3439	40.00
13.90	3443	3447	3451	3455	3459	3463	3467	3471	3475	3479	40.00
14.00	3483	3487	3491	3496	3500	3504	3508	3512	3516	3520	41.00
14.10	3524	3528	3532	3536	3540	3544	3548	3552	3556	3560	40.00
14.20	3564	3568	3573	3577	3581	3585	3589	3593	3597	3601	41.00
14.30	3605	3609	3613	3617	3621	3626	3630	3634	3638	3642	41.00
14.40	3646	3650	3654	3658	3662	3666	3671	3675	3679	3683	41.00

14.50	3687	3691	3695	3699	3703	3708	3712	3716	3720	3724	41.00
14.60	3728	3732	3736	3740	3745	3749	3753	3757	3761	3765	41.00
14.70	3769	3774	3778	3782	3786	3790	3794	3798	3803	3807	42.00
14.80	3811	3815	3819	3823	3827	3832	3836	3840	3844	3848	41.00
14.90	3852	3857	3861	3865	3869	3873	3877	3882	3886	3890	42.00
15.00	3894	3898	3902	3907	3911	3915	3919	3923	3928	3932	42.00
15.10	3936	3940	3944	3948	3953	3957	3961	3965	3969	3974	42.00
15.20	3978	3982	3986	3990	3995	3999	4003	4007	4012	4016	42.00
15.30	4020*	4024	4028	4033	4037	4041	4045	4050	4054	4058	42.00
15.40	4062	4067	4071	4075	4080	4084	4088	4092	4097	4101	43.00
15.50	4105	4109	4114	4118	4122	4126	4131	4135	4139	4144	43.00
15.60	4148	4152	4156	4161	4165	4169	4174	4178	4182	4186	43.00
15.70	4191	4195	4199	4204	4208	4212	4217	4221	4225	4229	43.00
15.80	4234	4238	4242	4247	4251	4255	4260	4264	4268	4273	43.00
15.90	4277	4281	4286	4290	4294	4299	4303	4307	4312	4316	43.00
16.00	4320	4325	4329	4333	4338	4342	4346	4351	4355	4359	44.00

16.10	4364	4368	4372	4377	4381	4385	4390	4394	4399	4403	43.00
16.20	4407	4412	4416	4420	4425	4429	4434	4438	4442	4447	44.00
16.30	4451	4455	4460	4464	4469	4473	4477	4482	4486	4490	44.00
16.40	4495	4499	4504	4508	4512	4517	4521	4526	4530	4534	44.00
16.50	4539	4543	4548	4552	4556	4561	4565	4570	4574	4579	44.00
16.60	4583	4587	4592	4596	4601	4605	4610	4614	4618	4623	44.00
16.70	4627	4632	4636	4641	4645	4649	4654	4658	4663	4667	45.00

EXPANDED RATING TABLE

TYPE: LOG

05058700 DATE PROCESSED: 01-21-1997 @ 10:55 BY JEWAGNER

SHEYENNE RIVER AT LISBON, ND DD: 7 TYPE: 001 RATING NO: 19.0

OFFSET: 1.50 START DATE/TIME: 10-01-94 (0015)

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION) .00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
16.80	4672	4676	4681	4685	4689	4694	4698	4703	4707	4712	44.00

16.90	4716	4721	4725	4730	4734	4738	4743	4747	4752	4756	45.00
17.00	4761	4765	4770	4774	4779	4783	4788	4792	4797	4801	45.00
17.10	4806	4810	4815	4819	4824	4828	4833	4837	4842	4846	45.00
17.20	4851	4855	4859	4864	4869	4873	4878	4882	4887	4891	45.00
17.30	4896	4900	4905	4909	4914	4918	4923	4927	4932	4936	45.00
17.40	4941	4945	4950	4954	4959	4963	4968	4972	4977	4981	45.00
17.50	4986	4991	4995	5000	5004	5009	5013	5018	5022	5027	45.00
17.60	5031	5036	5041	5045	5050	5054	5059	5063	5068	5072	46.00
17.70	5077	5082	5086	5091	5095	5100	5104	5109	5114	5118	46.00
17.80	5123	5127	5132	5136	5141	5146	5150	5155	5159	5164	46.00
17.90	5169	5173	5178	5182	5187	5191	5196	5201	5205	5210	45.00
18.00	5214	5219	5224	5228	5233	5238	5242	5247	5251	5256	47.00
18.10	5261	5265	5270	5274	5279	5284	5288	5293	5298	5302	46.00
18.20	5307	5311	5316	5321	5325	5330	5335	5339	5344	5348	46.00
18.30	5353	5358	5362	5367	5372	5376	5381	5386	5390	5395	47.00
18.40	5400	5404	5409	5414	5418	5423	5427	5432	5437	5441	46.00

18.50	5446	5451	5455	5460	5465	5469	5474	5479	5483	5488	47.00
18.60	5493	5498	5502	5507	5512	5516	5521	5526	5530	5535	47.00
18.70	5540	5544	5549	5554	5558	5563	5568	5573	5577	5582	47.00
18.80	5587	5591	5596	5601	5605	5610	5615	5620	5624	5629	47.00
18.90	5634	5638	5643	5648	5653	5657	5662	5667	5671	5676	47.00
19.00	5681	5686	5690	5695	5700	5705	5709	5714	5719	5723	47.00
19.10	5728	5733	5738	5742	5747	5752	5757	5761	5766	5771	48.00
19.20	5776	5780	5785	5790	5795	5799	5804	5809	5814	5818	47.00
19.30	5823	5828	5833	5838	5842	5847	5852	5857	5861	5866	48.00
19.40	5871	5876	5880	5885	5890	5895	5900	5904	5909	5914	48.00
19.50	5919	5924	5928	5933	5938	5943	5947	5952	5957	5962	48.00
19.60	5967	5971	5976	5981	5986	5991	5995	6000	6005	6010	48.00
19.70	6015	6020	6024	6029	6034	6039	6044	6048	6053	6058	48.00
19.80	6063	6068	6073	6077	6082	6087	6092	6097	6102	6106	48.00
19.90	6111	6116	6121	6126	6131	6135	6140	6145	6150	6155	49.00
20.00	6160	6164	6169	6174	6179	6184	6189	6194	6198	6203	48.00

20.10	6208	6213	6218	6223	6228	6232	6237	6242	6247	6252	49.00
20.20	6257	6262	6267	6271	6276	6281	6286	6291	6296	6301	49.00
20.30	6306	6310	6315	6320	6325	6330	6335	6340	6345	6350	48.00
20.40	6354	6359	6364	6369	6374	6379	6384	6389	6394	6399	49.00

1 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION PAGE 6

EXPANDED RATING TABLE

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OFFSET: 1.50 START DATE/TIME: 10-01-94 (0015)

DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)

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20.60	6453	6458	6462	6467	6472	6477	6482	6487	6492	6497	49.00
20.70	6502	6507	6512	6517	6522	6527	6531	6536	6541	6546	49.00
20.80	6551	6556	6561	6566	6571	6576	6581	6586	6591	6596	50.00

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   20.90    6601       6606       6611       6616       6621       6625       6630       6635       6640
6645         49.00

   21.00    6650       6655       6660       6665       6670       6675       6680       6685       6690
6695         50.00
   21.10    6700       6705       6710       6715       6720       6725       6730       6735       6740
6745         50.00
   21.20    6750       6755       6760       6765       6770       6775       6780       6785       6790
6795         50.00
   21.30    6800       6805       6810       6815       6820       6825       6830       6835       6840
6845         50.00
   21.40    6850       6855       6860       6865       6870       6875       6880       6885       6890
6895         50.00*

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  Chief, Hydrologic Records and Information Section<BR>
  U.S. Geological Survey<BR>
  821 East Interstate Avenue<BR>
  Bismarck, North Dakota 58501-1199<BR>
  (701) 250-7404 [Fax: (701) 250-7492]<BR>
  email: &lt;harkness@usgs.gov&gt;<BR>
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[U.S. Geological Survey] Water Resources of the United States
North Dakota
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05059000 SHEYENNE RIVER NEAR KINDRED, ND

LOCATION.--Lat 4637'54", long 9700'01", in SE1/4 SE1/4 SW1/4 sec.33, T.137 N., R.50 W., Cass County, Hydrologi Unit 09020204,
 on left bank 100 ft downstream from North Dakota State Highway 46 bridge crossing, 1.5 mi southeast of Kindred, and at mile 67.9.
DRAINAGE AREA.--8,800 mi2, approximately, of which about 5,780 mi2 is probably noncontributing, including 3,800 mi2 in closed basins.
WATER-DISCHARGE RECORDS
PERIOD OF RECORD.--July 1949 to current year.
REVISED RECORDS.--WSP 1728: Drainage area.
GAGE.--Water-stage recorder. Datum of gage is 925.55 ft above sea level. From Oct. 1, 1962, to Sept. 30, 1989, gage was located at site 1,500\x11ft upstream. July 1949 to Sept. 30, 1962, nonrecording gage at same site and datum.
REMARKS.--Records good except for period of estimated discharge, which are fair. Flow regulated to a large degree by Lake Ashtabula (station 05057500), 202 mi upstream, and several small reservoirs.
EXTREMES OUTSIDE PERIOD OF RECORD.--Spring flood in 1947 or 1948 reached a stage of 22.1 ft from floodmarks, discharge about 3,600 ft3/s.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1996 TO SEPTEMBER 1997
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	93	92	298	e200	e205	e200	e500	5420	1020	566	387	112
2	93	89	262	e200	e205	e210	e700	5270	913	472	370	108
3	93	129	233	e200	e205	e210	e1000	5020	743	437	350	93
4	97	134	280	e195	e205	e210	e1300	4910	649	394	333	92

5	101	137	324	e190	e208	e210	e1700	4910	670	359	279	97
6	94	125	358	e190	e210	e200	e2500	4950	924	332	229	110
7	86	131	363	e190	e210	e200	e3660	4920	940	342	209	153
8	82	139	345	e185	e210	e200	e5400	4790	749	444	194	136
9	79	138	359	e180	e210	e200	e5200	4670	626	564	186	113
10	78	121	347	e180	e210	e190	e4860	4510	535	600	182	102
11	75	112	347	e180	e210	e190	e4200	4290	526	580	182	99
12	75	73	311	e175	e210	e190	e3800	4060	513	563	189	115
13	74	90	264	e175	e210	e190	e3670	3760	495	685	184	150
14	74	126	232	e170	e210	e190	e3600	3320	455	763	173	146
15	74	155	e210	e170	e210	e190	e3600	2680	395	714	168	155
16	74	177	e170	e170	e210	e190	3770	2230	362	616	170	134
17	75	173	e150	e170	e210	e190	3670	2010	343	511	167	125
18	76	162	e140	e170	e200	e190	4150	1920	323	420	170	119
19	76	171	e120	e170	e200	e190	4650	1850	288	379	172	117
20	80	193	e117	e175	e200	e190	4770	1720	277	359	127	108

21	80	212	e120	e180	e200	e190	4710	1500	254	348	118	103
22	79	220	e140	e185	e200	e190	4650	1240	241	356	123	102
23	79	216	e160	e190	e200	e200	4770	1180	222	365	119	103
24	75	214	e160	e200	e200	e200	5000	1200	200	362	116	99
25	76	214	e155	e210	e200	e210	5190	1140	186	355	114	100
26	82	218	e150	e210	e190	e230	5410	1110	178	346	106	101
27	89	234	e155	e210	e190	e250	5540	1110	315	347	96	100
28	118	271	e170	e210	e190	e260	5570	1120	943	347	89	108
29	178	307	e190	e210	---	e250	5610	1130	975	340	88	109
30	172	319	e200	e200	---	e250	5570	1110	752	379	85	107
31	144	---	e200	e200	---	e350	---	1080	---	397	88	---
TOTAL	2821	5092	7030	5840	5718	6510	118720	90130	16012	14042	5563	3416
MEAN	91.0	170	227	188	204	210	3957	2907	534	453	179	114
MAX	178	319	363	210	210	350	5610	5420	1020	763	387	155
MIN	74	73	117	170	190	190	500	1080	178	332	85	92
AC-FT	5600	10100	13940	11580	11340	12910	235500	178800	31760	27850	11030	6780

STATISTICS OF MONTHLY MEAN DATA FOR WATER YEARS 1949 - 1997, BY WATER YEAR (WY)

MEAN	86.9	95.9	84.8	75.8	88.0	309	834	515	274	238	141	87.3
MAX	693	589	339	205	317	1256	3957	3053	1938	1466	2231	483
(WY)	1995	1995	1995	1995	1996	1987	1997	1950	1950	1975	1993	1993
MIN	24.6	22.7	17.6	17.5	21.7	35.1	71.7	53.6	48.4	26.7	17.5	25.1
(WY)	1957	1956	1956	1991	1956	1956	1991	1990	1961	1988	1988	1959

SUMMARY STATISTICS	FOR 1996 CALENDAR YEAR		FOR 1997 WATER YEAR		WATER YEARS 1949 - 1997		
ANNUAL TOTAL	249958		280894				
ANNUAL MEAN	683		770		236		
HIGHEST ANNUAL MEAN					770		1997
LOWEST ANNUAL MEAN					48.0		1991
HIGHEST DAILY MEAN	5010	Apr 30	5610	Apr 29	5610	Apr 29	1997
LOWEST DAILY MEAN	71	Sep 18	73	Nov 12	9.2	Aug 16	1990
ANNUAL SEVEN-DAY MINIMUM	74	Sep 14	74	Oct 11	11	Dec 26	1990
INSTANTANEOUS PEAK FLOW			5970	Apr 27	5970	Apr 27	1997
INSTANTANEOUS PEAK STAGE			a22.33	Apr 8	a22.33	Apr 8	1997
ANNUAL RUNOFF (AC-FT)	495800		557200		171100		
10 PERCENT EXCEEDS	1750		3600		488		
50 PERCENT EXCEEDS	253		205		85		

90 PERCENT EXCEEDS	86	97	34

a Backwater from ice.
e Estimated.

05059000 SHEYENNE RIVER NEAR KINDRED, ND--Continued

WATER-QUALITY RECORDS

PERIOD OF RECORD.--Water year 1972 to current year.

WATER-QUALITY DATA, WATER YEAR OCTOBER 1996 TO SEPTEMBER 1997

DATE	TIME	DIS-CHARGE, INST. CUBIC FEET PER SECOND (00061)	SPE-CIFIC CON-DUCT-ANCE (US/CM) (00095)	PH WATER WHOLE FIELD (STAND-ARD UNITS) (00400)	TEMPER-ATURE AIR (DEG C) (00020)	TEMPER-ATURE WATER (DEG C) (00010)	HARD-NESS TOTAL (MG/L AS CACO3) (00900)	ALKA-LINITY LAB (MG/L AS CACO3) (90410)	CALCIUM DIS-SOLVED (MG/L AS CA) (00915)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG) (00925)
OCT										
03...	1025	954	1040	--	9.0	8.5	--	--	--	--
NOV										
08...	1350	141	1070	--	5.5	2.5	--	--	--	--
DEC										
20...	1410	117	1090	--	-10.0	0.5	--	--	--	--
FEB										
05...	1510	208	1110	--	-0.5	0.5	--	--	--	--
APR										
10...	1615	4860	705	--	-3.0	1.0	--	--	--	--
16...	1530	3650	584	8.0	4.0	3.0	210	137	49	22
22...	1110	4610	--	--	12.0	7.5	--	--	--	--
26...	1405	5600	596	--	17.0	9.0	--	--	--	--
30...	1120	5570	577	--	5.0	10.0	--	--	--	--
MAY										
19...	1400	1850	760	--	6.0	13.0	--	--	--	--

JUN										
03...	1530	720	860	--	22.0	20.0	--	--	--	--
JUL										
31...	1140	398	1030	--	23.0	23.5	--	--	--	--

DATE	SODIUM, DIS- SOLVED (MG/L AS NA) (00930)	SODIUM PERCENT (00932)	SODIUM AD- SORP- TION RATIO (00931)	POTAS- SIUM, DIS- SOLVED (MG/L AS K) (00935)	SULFATE DIS- SOLVED (MG/L AS SO4) (00945)	CHLO- RIDE, DIS- SOLVED (MG/L AS CL) (00940)	FLUO- RIDE, DIS- SOLVED (MG/L AS F) (00950)	SOLIDS, SUM OF CONSTI- TUENTS, DIS- SOLVED (MG/L) (70301)	SOLIDS, RESIDUE AT 180 DEG. C DIS- SOLVED (MG/L) (70300)	SOLIDS, DIS- SOLVED (TONS PER AC-FT) (70303)
APR										
16...	32	24	1	8.8	140	12	0.20	347	373	0.51

DATE	SOLIDS, DIS- SOLVED (TONS PER DAY) (70302)	ARSENIC DIS- SOLVED (UG/L AS AS) (01000)	IRON, DIS- SOLVED (UG/L AS FE) (01046)	LEAD, DIS- SOLVED (UG/L AS PB) (01049)	LITHIUM DIS- SOLVED (UG/L AS LI) (01130)	MANGA- NESE, DIS- SOLVED (UG/L AS MN) (01056)	MERCURY DIS- SOLVED (UG/L AS HG) (71890)	MOLYB- DENUM, DIS- SOLVED (UG/L AS MO) (01060)	SELE- NIUM, DIS- SOLVED (UG/L AS SE) (01145)	STRON- TIUM, DIS- SOLVED (UG/L AS SR) (01080)
APR										
16...	3680	2	60	<1.0	30	130	<0.1	<1.0	<1	250

[U.S. Department of Interior] [U.S. Geological Survey]

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Chief, Hydrologic Records and Information Section
U.S. Geological Survey
821 East Interstate Avenue
Bismarck, North Dakota 58501-1199
(701) 250-7404 [Fax: (701) 250-7492]
email: <harkness@usgs.gov>

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BASED ON ________ DISCHARGE MEASUREMENTS, NOS _________, AND _________, AND IS _______ WELL DEFINED BETWEEN _____ AND _______ CFS

COMP BY ______ DATE _________ CHK. BY ______ DATE _________

High-water revision of RT 14. REH 5/3/96

DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)

GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
2.20	20.00*	21.47	22.96	24.49	26.05	27.64	29.26	30.90	32.57	34.27	16.00
2.30	36.00*	37.62	39.26	40.92	42.60	44.29	46.00	47.73	49.47	51.23	17.00
2.40	53.00*	54.74	56.50	58.27	60.05	61.84	63.65	65.47	67.30	69.14	18.00
2.50	71.00*	72.85	74.72	76.59	78.47	80.37	82.28	84.19	86.12	88.05	19.00
2.60	90.00*	91.87	93.74	95.62	97.51	99.41	101.3	103.2	105.1	107.1	19.00
2.70	109.0*	110.9	112.8	114.6	116.5	118.4	120.3	122.2	124.2	126.1	19.00
2.80	128.0*	130.0	132.0	133.9	135.9	137.9	139.9	141.9	144.0	146.0	20.00
2.90	148.0*	150.0	152.0	154.0	155.9	157.9	159.9	162.0	164.0	166.0	20.00

3.00	168.0*	169.8	171.7	173.5	175.3	177.2	179.0	180.8	182.7	184.5	18.30
3.10	186.3	188.2	190.0	191.9	193.7	195.6	197.4	199.3	201.1	203.0	18.50
3.20	204.8	206.7	208.6	210.4	212.3	214.1	216.0	217.9	219.7	221.6	18.70
3.30	223.5	225.3	227.2	229.1	231.0	232.8	234.7	236.6	238.5	240.3	18.70
3.40	242.2	244.1	246.0	247.9	249.8	251.6	253.5	255.4	257.3	259.2	18.90
3.50	261.1	263.0	264.9	266.8	268.7	270.6	272.5	274.4	276.3	278.2	19.00
3.60	280.1	282.0	283.9	285.8	287.7	289.6	291.5	293.4	295.3	297.3	19.10
3.70	299.2	301.1	303.0	304.9	306.8	308.7	310.7	312.6	314.5	316.4	19.20
3.80	318.4	320.3	322.2	324.1	326.1	328.0	329.9	331.8	333.8	335.7	19.20
3.90	337.6	339.6	341.5	343.4	345.4	347.3	349.2	351.2	353.1	355.1	19.40
4.00	357.0*	358.8	360.5	362.3	364.0	365.8	367.5	369.3	371.0	372.8	17.60
4.10	374.6	376.3	378.1	379.8	381.6	383.3	385.1	386.8	388.6	390.3	17.50
4.20	392.1	393.8	395.6	397.4	399.1	400.9	402.6	404.4	406.1	407.9	17.50
4.30	409.6	411.4	413.1	414.9	416.6	418.4	420.1	421.9	423.6	425.4	17.50
4.40	427.1	428.9	430.6	432.4	434.1	435.9	437.6	439.4	441.1	442.9	17.50
4.50	444.6	446.4	448.1	449.9	451.6	453.4	455.1	456.9	458.6	460.4	17.50

4.60	462.1	463.9	465.6	467.4	469.1	470.9	472.6	474.4	476.1	477.9	17.50
4.70	479.6	481.4	483.1	484.9	486.6	488.4	490.1	491.8	493.6	495.3	17.50
4.80	497.1	498.8	500.6	502.3	504.1	505.8	507.6	509.3	511.1	512.8	17.40
4.90	514.5	516.3	518.0	519.8	521.5	523.3	525.0	526.8	528.5	530.3	17.50
5.00	532.0*	533.6	535.3	536.9	538.5	540.2	541.8	543.5	545.1	546.8	16.40
5.10	548.4	550.0	551.7	553.3	555.0	556.6	558.3	559.9	561.6	563.2	16.50
5.20	564.9	566.6	568.2	569.9	571.5	573.2	574.8	576.5	578.2	579.8	16.60
5.30	581.5	583.1	584.8	586.5	588.1	589.8	591.5	593.1	594.8	596.5	16.70
5.40	598.2	599.8	601.5	603.2	604.9	606.5	608.2	609.9	611.6	613.2	16.70
5.50	614.9	616.6	618.3	620.0	621.7	623.3	625.0	626.7	628.4	630.1	16.90
5.60	631.8	633.5	635.2	636.8	638.5	640.2	641.9	643.6	645.3	647.0	16.90
5.70	648.7	650.4	652.1	653.8	655.5	657.2	658.9	660.6	662.3	664.0	17.00
5.80	665.7	667.4	669.1	670.8	672.6	674.3	676.0	677.7	679.4	681.1	17.10
5.90	682.8	684.5	686.3	688.0	689.7	691.4	693.1	694.8	696.6	698.3	17.20

EXPANDED RATING TABLE

TYPE: LOG

05059000 DATE PROCESSED: 01-21-1997 @ 10:57 BY JEWAGNER
SHEYENNE RIVER NEAR KINDRED, ND DD: 9 TYPE: 001 RATING NO: 15.0
OFFSET: 2.00 BREAK,OFFSET: (5.00,1.00) (16.00,.00) START DATE/TIME: 10-04-95 (0015)

High-water revision of RT 14. REH 5/3/96

DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)

GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
6.00	700.0*	701.6	703.2	704.7	706.3	707.9	709.5	711.1	712.7	714.2	15.80
6.10	715.8	717.4	719.0	720.6	722.2	723.8	725.3	726.9	728.5	730.1	15.90
6.20	731.7	733.3	734.9	736.5	738.1	739.6	741.2	742.8	744.4	746.0	15.90
6.30	747.6	749.2	750.8	752.4	754.0	755.6	757.2	758.8	760.4	761.9	15.90
6.40	763.5	765.1	766.7	768.3	769.9	771.5	773.1	774.7	776.3	777.9	16.00
6.50	779.5	781.1	782.7	784.3	785.9	787.5	789.1	790.7	792.3	793.9	16.00
6.60	795.6	797.2	798.8	800.4	802.0	803.6	805.2	806.8	808.4	810.0	16.00
6.70	811.6	813.2	814.8	816.4	818.0	819.7	821.3	822.9	824.5	826.1	16.10
6.80	827.7	829.3	830.9	832.5	834.2	835.8	837.4	839.0	840.6	842.2	16.10
6.90	843.8	845.4	847.1	848.7	850.3	851.9	853.5	855.1	856.8	858.4	16.20

7.00	860.0*	861.6	863.2	864.8	866.3	867.9	869.5	871.1	872.7	874.3	15.90
7.10	875.9	877.5	879.1	880.6	882.2	883.8	885.4	887.0	888.6	890.2	15.90
7.20	891.8	893.4	895.0	896.6	898.2	899.7	901.3	902.9	904.5	906.1	15.90
7.30	907.7	909.3	910.9	912.5	914.1	915.7	917.3	918.9	920.5	922.1	16.00
7.40	923.7	925.3	926.9	928.5	930.1	931.7	933.3	934.9	936.5	938.1	16.00
7.50	939.7	941.3	942.9	944.5	946.1	947.7	949.3	950.9	952.5	954.1	16.00
7.60	955.7	957.3	958.9	960.5	962.1	963.7	965.3	966.9	968.5	970.1	16.00
7.70	971.7	973.3	974.9	976.5	978.1	979.8	981.4	983.0	984.6	986.2	16.10
7.80	987.8	989.4	991.0	992.6	994.2	995.8	997.4	999.1	1001	1002	16.20
7.90	1004	1005	1007	1009	1010	1012	1014	1015	1017	1018	16.00
8.00	1020*	1022	1023	1025	1026	1028	1030	1031	1033	1034	16.00
8.10	1036	1038	1039	1041	1042	1044	1045	1047	1049	1050	16.00
8.20	1052	1053	1055	1057	1058	1060	1061	1063	1065	1066	16.00
8.30	1068	1069	1071	1073	1074	1076	1077	1079	1081	1082	16.00
8.40	1084	1085	1087	1089	1090	1092	1093	1095	1097	1098	16.00
8.50	1100	1101	1103	1105	1106	1108	1109	1111	1113	1114	16.00

8.60	1116	1117	1119	1121	1122	1124	1125	1127	1129	1130	16.00
8.70	1132	1133	1135	1137	1138	1140	1141	1143	1145	1146	16.00
8.80	1148	1149	1151	1153	1154	1156	1157	1159	1161	1162	16.00
8.90	1164	1166	1167	1169	1170	1172	1174	1175	1177	1178	16.00
9.00	1180*	1182	1184	1186	1188	1190	1192	1194	1196	1198	20.00
9.10	1200	1202	1204	1206	1208	1209	1211	1213	1215	1217	19.00
9.20	1219	1221	1223	1225	1227	1229	1231	1233	1235	1237	20.00
9.30	1239	1241	1243	1245	1247	1249	1251	1253	1255	1257	20.00
9.40	1259	1261	1263	1265	1267	1269	1271	1273	1275	1277	20.00
9.50	1279	1281	1283	1285	1287	1289	1291	1293	1295	1297	20.00
9.60	1299	1301	1303	1305	1307	1309	1311	1313	1315	1317	20.00
9.70	1319	1321	1323	1325	1327	1329	1331	1333	1335	1337	20.00

EXPANDED RATING TABLE

TYPE: LOG

05059000 DATE PROCESSED: 01-21-1997 @ 10:57 BY JEWAGNER

SHEYENNE RIVER NEAR KINDRED, ND DD: 9 TYPE: 001 RATING NO: 15.0

OFFSET: 2.00 BREAK,OFFSET: (5.00,1.00) (16.00,.00) START DATE/TIME: 10-04-95 (0015)

High-water revision of RT 14. REH 5/3/96

GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)											
9.80	1339	1341	1343	1345	1347	1350	1352	1354	1356	1358	21.00
9.90	1360	1362	1364	1366	1368	1370	1372	1374	1376	1378	20.00
10.00	1380*	1382	1384	1386	1388	1390	1392	1394	1396	1398	20.00
10.10	1400	1402	1404	1406	1408	1410	1412	1414	1416	1418	20.00
10.20	1420	1421	1423	1425	1427	1429	1431	1433	1435	1437	19.00
10.30	1439	1441	1443	1445	1447	1449	1451	1453	1455	1457	20.00
10.40	1459	1461	1463	1465	1467	1469	1471	1473	1475	1477	20.00
10.50	1479	1481	1483	1485	1487	1489	1491	1493	1495	1497	20.00
10.60	1499	1501	1503	1505	1507	1509	1511	1513	1515	1517	20.00
10.70	1519	1521	1523	1525	1527	1529	1531	1533	1535	1538	21.00
10.80	1540	1542	1544	1546	1548	1550	1552	1554	1556	1558	20.00
10.90	1560	1562	1564	1566	1568	1570	1572	1574	1576	1578	20.00

11.00	1580*	1582	1584	1586	1588	1590	1592	1594	1596	1598	20.00
11.10	1600	1602	1604	1606	1608	1610	1612	1614	1616	1618	20.00
11.20	1620	1622	1624	1626	1628	1630	1632	1634	1636	1638	19.00
11.30	1639	1641	1643	1645	1647	1649	1651	1653	1655	1657	20.00
11.40	1659	1661	1663	1665	1667	1669	1671	1673	1675	1677	20.00
11.50	1679	1681	1683	1685	1687	1689	1691	1693	1695	1697	20.00
11.60	1699	1701	1703	1705	1707	1709	1711	1713	1715	1717	20.00
11.70	1719	1722	1724	1726	1728	1730	1732	1734	1736	1738	21.00
11.80	1740	1742	1744	1746	1748	1750	1752	1754	1756	1758	20.00
11.90	1760	1762	1764	1766	1768	1770	1772	1774	1776	1778	20.00
12.00	1780*	1782	1784	1786	1788	1790	1792	1794	1796	1798	20.00
12.10	1800	1802	1804	1806	1808	1810	1812	1814	1816	1818	20.00
12.20	1820	1822	1824	1826	1828	1830	1832	1834	1836	1838	20.00
12.30	1840	1842	1844	1846	1848	1850	1852	1854	1856	1858	20.00
12.40	1860	1862	1864	1866	1868	1870	1872	1874	1876	1878	20.00
12.50	1880	1882	1884	1886	1888	1890	1892	1894	1896	1898	20.00

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   12.60    1900       1902       1904       1906       1908       1910       1912       1914       1916
1918         20.00
   12.70    1920       1922       1924       1926       1928       1930       1932       1934       1936
1938         20.00
   12.80    1940       1942       1944       1946       1948       1950       1952       1954       1956
1958         20.00
   12.90    1960       1962       1964       1966       1968       1970       1972       1974       1976
1978         20.00

   13.00    1980*      1982       1984       1986       1988       1990       1992       1994       1996
1998         20.00
   13.10    2000       2002       2004       2006       2008       2010       2012       2014       2016
2018         20.00
   13.20    2020       2022       2024       2026       2028       2030       2032       2034       2036
2038         20.00
   13.30    2040       2042       2044       2046       2048       2050       2052       2054       2056
2058         20.00
   13.40    2060       2062       2064       2066       2068       2070       2072       2074       2076
2078         20.00

1                        UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
             PAGE  4
                                                        EXPANDED RATING TABLE
      TYPE: LOG
 05059000                                               DATE PROCESSED: 01-21-1997 @ 10:57 BY JEWAGNER
 SHEYENNE RIVER NEAR KINDRED, ND                                                                DD:    9    TYPE:
001    RATING NO: 15.0
 OFFSET: 2.00  BREAK,OFFSET: (5.00,1.00) (16.00,.00)                                                       START
DATE/TIME: 10-04-95  (0015)
                                                        High-water revision of RT 14.  REH 5/3/96
    GAGE
           DIFF IN Q
   HEIGHT                        DISCHARGE IN CUBIC FEET PER SECOND          (EXPANDED PRECISION)
              PER
```

(FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	TENTH FT
13.50	2080	2082	2084	2086	2088	2090	2092	2094	2096	2098	20.00
13.60	2100	2102	2104	2106	2108	2110	2112	2114	2116	2118	20.00
13.70	2120	2122	2124	2126	2128	2130	2132	2134	2136	2138	20.00
13.80	2140	2142	2144	2146	2148	2150	2152	2154	2156	2158	20.00
13.90	2160	2162	2164	2166	2168	2170	2172	2174	2176	2178	20.00
14.00	2180*	2182	2184	2186	2188	2190	2192	2194	2196	2198	20.00
14.10	2200	2202	2204	2206	2208	2210	2212	2214	2216	2218	20.00
14.20	2220	2222	2224	2226	2228	2230	2232	2234	2236	2238	20.00
14.30	2240	2242	2244	2246	2248	2250	2252	2254	2256	2258	20.00
14.40	2260	2262	2264	2266	2268	2270	2272	2274	2276	2278	20.00
14.50	2280	2282	2284	2286	2288	2290	2292	2294	2296	2298	20.00
14.60	2300	2302	2304	2306	2308	2310	2312	2314	2316	2318	20.00
14.70	2320	2322	2324	2326	2328	2330	2332	2334	2336	2338	20.00
14.80	2340	2342	2344	2346	2348	2350	2352	2354	2356	2358	20.00
14.90	2360	2362	2364	2366	2368	2370	2372	2374	2376	2378	20.00

15.00	2380*	2382	2384	2387	2389	2391	2393	2395	2397	2400	22.00
15.10	2402	2404	2406	2408	2411	2413	2415	2417	2419	2421	22.00
15.20	2424	2426	2428	2430	2432	2435	2437	2439	2441	2443	22.00
15.30	2446	2448	2450	2452	2454	2457	2459	2461	2463	2465	21.00
15.40	2467	2470	2472	2474	2476	2478	2481	2483	2485	2487	22.00
15.50	2489	2492	2494	2496	2498	2500	2503	2505	2507	2509	22.00
15.60	2511	2514	2516	2518	2520	2523	2525	2527	2529	2531	23.00
15.70	2534	2536	2538	2540	2542	2545	2547	2549	2551	2553	22.00
15.80	2556	2558	2560	2562	2565	2567	2569	2571	2573	2576	22.00
15.90	2578	2580	2582	2584	2587	2589	2591	2593	2596	2598	22.00
16.00	2600*	2602	2605	2607	2610	2612	2614	2617	2619	2621	24.00
16.10	2624	2626	2629	2631	2633	2636	2638	2641	2643	2645	24.00
16.20	2648	2650	2653	2655	2657	2660	2662	2665	2667	2669	24.00
16.30	2672	2674	2677	2679	2681	2684	2686	2689	2691	2693	24.00
16.40	2696	2698	2701	2703	2706	2708	2710	2713	2715	2718	24.00
16.50	2720*	2723	2725	2728	2730	2733	2735	2738	2741	2743	26.00

16.60 2746 2748 2751 2754 2756 2759 2761 2764 2767
2769 26.00
16.70 2772 2774 2777 2780 2782 2785 2787 2790 2793
2795 26.00
16.80 2798 2800 2803 2806 2808 2811 2813 2816 2819
2821 26.00
16.90 2824 2826 2829 2832 2834 2837 2840 2842 2845
2847 26.00

17.00 2850* 2853 2857 2860 2864 2867 2870 2874 2877
2881 34.00
17.10 2884 2887 2891 2894 2898 2901 2905 2908 2911
2915 34.00
17.20 2918 2922 2925 2929 2932 2936 2939 2942 2946
2949 35.00
1 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
PAGE 5
EXPANDED RATING TABLE
TYPE: LOG
05059000 DATE PROCESSED: 01-21-1997 @ 10:57 BY JEWAGNER
SHEYENNE RIVER NEAR KINDRED, ND DD: 9 TYPE:
001 RATING NO: 15.0
OFFSET: 2.00 BREAK,OFFSET: (5.00,1.00) (16.00,.00) START
DATE/TIME: 10-04-95 (0015)
High-water revision of RT 14. REH 5/3/96
GAGE
DIFF IN Q
HEIGHT DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)
PER
(FEET) .00 .01 .02 .03 .04 .05 .06 .07 .08
.09 TENTH FT

17.30 2953 2956 2960 2963 2967 2970 2974 2977 2981
2984 35.00

17.40	2988	2991	2994	2998	3001	3005	3008	3012	3015	3019	34.00
17.50	3022	3026	3029	3033	3036	3040	3043	3047	3050	3054	36.00
17.60	3058	3061	3065	3068	3072	3075	3079	3082	3086	3089	35.00
17.70	3093	3096	3100	3103	3107	3111	3114	3118	3121	3125	35.00
17.80	3128	3132	3135	3139	3143	3146	3150	3153	3157	3160	36.00
17.90	3164	3168	3171	3175	3178	3182	3186	3189	3193	3196	36.00
18.00	3200*	3204	3208	3212	3216	3219	3223	3227	3231	3235	39.00
18.10	3239	3243	3247	3251	3254	3258	3262	3266	3270	3274	39.00
18.20	3278	3282	3286	3290	3294	3298	3302	3305	3309	3313	39.00
18.30	3317	3321	3325	3329	3333	3337	3341	3345	3349	3353	40.00
18.40	3357	3361	3365	3369	3373	3377	3381	3385	3389	3393	40.00
18.50	3397	3401	3405	3409	3413	3417	3421	3425	3429	3433	40.00
18.60	3437	3441	3445	3449	3453	3457	3461	3465	3469	3473	40.00
18.70	3477	3481	3485	3489	3494	3498	3502	3506	3510	3514	41.00
18.80	3518	3522	3526	3530	3534	3538	3542	3547	3551	3555	41.00
18.90	3559	3563	3567	3571	3575	3579	3584	3588	3592	3596	41.00

19.00	3600*	3606	3612	3618	3625	3631	3637	3643	3649	3655	62.00
19.10	3662	3668	3674	3680	3687	3693	3699	3705	3712	3718	62.00
19.20	3724	3730	3737	3743	3749	3756	3762	3768	3775	3781	63.00
19.30	3787	3794	3800	3806	3813	3819	3825	3832	3838	3845	64.00
19.40	3851	3857	3864	3870	3877	3883	3890	3896	3903	3909	65.00
19.50	3916	3922	3929	3935	3942	3948	3955	3961	3968	3974	65.00
19.60	3981	3988	3994	4001	4007	4014	4021	4027	4034	4040	66.00
19.70	4047	4054	4060	4067	4074	4080	4087	4094	4101	4107	67.00
19.80	4114	4121	4127	4134	4141	4148	4154	4161	4168	4175	68.00
19.90	4182	4188	4195	4202	4209	4216	4223	4229	4236	4243	68.00
20.00	4250*	4260	4269	4279	4288	4298	4308	4317	4327	4337	97.00
20.10	4347	4356	4366	4376	4386	4395	4405	4415	4425	4435	98.00
20.20	4445	4455	4465	4475	4485	4495	4505	4515	4525	4535	100.0
20.30	4545	4555	4565	4575	4585	4595	4606	4616	4626	4636	102.0
20.40	4647	4657	4667	4677	4688	4698	4708	4719	4729	4740	103.0
20.50	4750*	4772	4795	4818	4841	4863	4886	4910	4933	4956	229.0

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   20.60    4979       5003       5027       5050       5074       5098       5122       5146       5170
5194        240.0
   20.70    5219       5243       5268       5293       5317       5342       5367       5392       5418
5443        249.0
   20.80    5468       5494       5520       5545       5571       5597       5623       5649       5676
5702        261.0
   20.90    5729       5755       5782       5809       5836       5863       5890       5917       5945
5972        271.0*

1                        UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
             PAGE  6
                                                        EXPANDED RATING TABLE
      TYPE: LOG
 05059000                                               DATE PROCESSED: 01-21-1997 @ 10:57 BY JEWAGNER
 SHEYENNE RIVER NEAR KINDRED, ND                                                         DD:    9    TYPE:
001    RATING NO: 15.0
 OFFSET: 2.00  BREAK,OFFSET: (5.00,1.00) (16.00,.00)                                         START
DATE/TIME: 10-04-95  (0015)
                                                        High-water revision of RT 14.  REH 5/3/96
    GAGE
           DIFF IN Q
   HEIGHT                     DISCHARGE IN CUBIC FEET PER SECOND          (EXPANDED PRECISION)
              PER
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  .09      TENTH FT

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  U.S. Geological Survey<BR>
  821 East Interstate Avenue<BR>
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Glossary

anisotropy—condition in which the magnitude of a physical characteristic varies with direction (e.g., hydraulic conductivity).

aquifer—a formation, group of formations, or part of a formation that contains sufficient saturated, permeable material to yield significant quantities of water to wells and springs.

aquitard— see confining unit.

artesian aquifer—see confined aquifer.

available drawdown—for a pumping well, the distance from static water level to approximately 5 feet to 10 feet above the pump intake.

barometric efficiency—ratio of changes in water level in well to the change in atmospheric pressure in consistent units.

blowout–a general term for various saucer-, cup-, or through-shaped hollows formed by wind erosion on a preexisting dune or other sand deposit.

boundary effects—influences on groundwater flow within an aquifer due to hydraulic features in hydraulic connection with the aquifer, e.g., rivers, lakes, faults, leaky confining units, etc. Boundary effects may increase or decrease the amount of drawdown that would occur if the aquifer were of infinite areal extent.

bounded aquifer-an aquifer of limited areal extent, bounded either by impermeable material (no-flow boundary) or material capable of supplying a limited amount of water to the aquifer or receiving a limited amount of water from the aquifer (head-dependent boundary), or material supplying or receiving an essentially unlimited amount of water (constant head boundary.)

casing storage effect—deviation from the predicted time-drawdown curve in an observation well caused by pumping of water from storage in the well casing. The result is understressing of the aquifer early in the pumping phase. This effect usually dissipates within the first few minutes of the test.

cone of depression—an area of lowered head centered on a pumping well.

confined aquifer—(artesian aquifer) an aquifer in which the water levels in wells stand above the top of the aquifer, and that, when pumped, receives no recharge from or through the confining layers above or below the aquifer.

confining unit—a unit that has significantly lower ability to transmit water than the aquifers that it separates.

Cretaceous–the third and latest of the periods in the Mesozoic Era.

delayed gravity response—a characteristic of unconfined aquifers, the rate of drawdown in response to pumping declines temporarily due to draining of the dewatered part of the aquifer under the influence of gravity.

delta–an alluvial depost, usually triangular, at the mount of a river; a deposit of sediment formed at the mouth of a river either in the ocean or a lake which results in progradation of the shore line.

drawdown—reduction in head in response to pumping, the difference between static water level and the water level at a given time during the pumping phase of a pumping test.

drift–any rock material, such as boulders, till, gravel, sand, or clay, transported by a glacier and deposited by or from the ice or by or in water derived from the melting of the ice. Generally used of the glaical deposits of the Pleistocene Epoch.

dune–a low hill or bank of drifted sand; mounds and ridges of wind-blown or eolian sand are dunes.

elastic response—release of water from storage in an aquifer as the aquifer material compresses and the water expands due to lowering of pressure as a well is pumped.

flowing well—a well completed in a confined aquifer at a point where the head is at a higher elevation than the top of the well casing.

fluvial–pertaining to rivers and streams.

full penetration—condition in which a well is screened over the entire saturated thickness of an aquifer.

gage pressure—(cf absolute pressure) pressure in excess of atmospheric pressure.

Holocene–pertaining to the Epoch of the Quaternary Period from the approximate end of continental glaciation to the present time.

hydraulic conductivity—the volume of water at the existing viscosity that will move in unit time under a unit hydraulic gradient through a unit area of aquifer measured at right angles to the direction of flow.

hydraulic gradient— the difference in hydraulic head between two measuring points divided by the distance between the measuring points.

hydraulic head—the level to which water in a well would rise measured relative to a datum, commonly sea level.

interference effects—changes in water levels caused by changes of stress on the aquifer other than pumping well designated for an aquifer test. Interference effects can arise from cycling of pumps in other wells, changes in barometric pressure, changes in river stage or lake level, tides, etc.

kame–a conical hill or short irregular ridge of gravel or sand deposited in contact with glacier ice.

lacustrine–pertaining to lakes.

leaky-confined aquifer—an aquifer in which the water levels in wells stand above the top of the aquifer and that, when pumped, receives discharge from a bounding confining layer or from another aquifer through the intervening confining layer.

moraine–drift, deposied chiefly by direct glacial action and having constructional topography independent of control by the surface on which the drift lies. Examples include bottom moraine, terminal moraine, and end moraine.

orifice tube—device used to measure flow rate. Consists of a pipe with a smaller-diameter, circular opening and a piezometer on the pipe centerline. The pressure in the pipe, measured as height of water in the piezometer, is converted to flow rate using charts such as Attachment 7.

outwash–unconsolidated deposits, chiefly sand and gravel, deposited broadly by streams coming off of glaciers.

partial penetration—condition in which a well is screened over part of the saturated thickness of an aquifer.

permeability—term commonly used as synonymous with hydraulic conductivity. However, the term intrinsic permeability refers to the proportionality constant relating discharge to fluid characteristics and hydraulic gradient (Freeze and Cherry, 1979, p. 27).

Pleistocene–the earlier of two Epochs comprising the Quaternary Period; the time when continental glaciation last occured.

Precambrian–pertaining to rocks deposited before the Cambrian Era; the oldest rocks on earth.

Quaternary–The younger of the two geologic periods or systems in the Cenozoic Era. Quaternary is subdivided into Pleistocene and Holocone (or recent) epochs.

residual drawdown—the difference between static water level and the water level at a given time during the recovery phase of a pumping test.

saturated thickness—distance between the top and bottom of an aquifer.

specific capacity—ratio of pumping rate of a well divided by the drawdown measured in the well after the water level has stabilized.

specific retention—ratio of the volume of water retained against the force of gravity in a porous material to the volume of material, due to capillary action.

specific storage—the volume of water a confined aquifer releases from or takes into storage per unit surface area of aquifer per unit change in head (storage coefficient) divided by the saturated thickness.

specific yield—the ratio of (1) the volume of water that saturated porous material under water table conditions will yield by gravity to (2) the volume of the saturated material.

steady-state stage—the later part of a pumping test, during which the rate of drawdown becomes negligible.

storage coefficient—the volume of water a confined aquifer releases from or takes into storage per unit surface area of aquifer per unit change in head.

Theis equation—analytical solution for drawdown during pumping of a confined aquifer of infinite areal extent.

Theis curve—time-drawdown curve based on the Theis equation. See Attachment __.

till–nonsorted, nonstratified sediment carried or deposited by a glacier.

transient - time-dependent

transient stage of a pumping test—the early part of a pumping test, during which the rate of drawdown is rapid.

transmissivity—that rate at which water of the prevailing viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

type curve—time-drawdown curve based on an analytical solution (e.g., Theis equation). Actual field measurements may be matched to the type curve to determine aquifer parameters.

unconfined aquifer—(water table aquifer) an aquifer in which the water levels in wells define the top of the aquifer (i.e., unsaturated material with similar texture lies above the water table).

well interference—water-level changes measured in a pumped well or observation caused by another pumped well.

well loss—reduction in the water level in a well during pumping due to losses of energy from turbulence or friction in the well screen and pump.

Explanation of Symbols Used in Report

b—saturated thickness

h—hydraulic head

K—hydraulic conductivity

Q—pumping rate

Q/s—specific capacity of a pumping well

r—radius from pumping well to observation well

s—drawdown

S—storage term (either storage coefficient for confined aquifers or specific yield for unconfined aquifers)

S_s—specific storage

S_c—storage coefficient, storage term for a confined aquifer

S_y—specific yield, storage term for an unconfined aquifer

T—transmissivity

t—time

u—dimensionless argument of the well function (W(u))

W(u)—the Theis well function

Appendix F
Details on the Cross-sectional MODFLOW Models

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Appendix F
Details on the Cross-sectional MODFLOW Models

Modeling Methods

Modeling was performed using a modification of the public domain version of MODFLOW'96. The modification allows more stable performance as suggested by Dr. John Doherty, the author of the parameter estimation software PEST. The block-centered flow module was modified to prevent unconfined cells from drying up. If the head in the cell dropped below the base elevation of the cell, the saturated thickness was set to 1 meter and the cell was then treated as confined (i.e., the head for each cell was set so inflow and outflow to the cell balance without regard to the elevation of the base of the cell). The effect of this modification is to allow the model to remain stable under changing conditions by preventing the downgradient "cascading" of dry, inactive cells as upgradient cells dry up. This approach allows for continuity in the flow system. Such a modification allows the use of horizontal layers in a system such as the Sheyenne Delta aquifer, which has large relief relative to the saturated thickness of the aquifer.

Five simulations were run for each cross-section: a steady-state model of typical summer conditions (used to set the initial conditions for the Baldhill Dam Pool Raise simulation), a transient simulation of a typical 100-year flood event with and without the effects of the Baldhill Dam Pool Raise, and a transient simulation of a typical year with and without the effects of the Devils Lake Outlet. Selected input files for cross-section model 2 are included below. The input files listed below include all the files for the steady-state simulation and those files controlling transient stresses on the system for the other two simulations. The models were set up using ArcView coverages with universal transverse mercator projections (metric units), consequently all length units in the input files are in meters. Time units for the model are days.

Modeling Results

Figures F-1 through F-5 show the model results from cross-section model 2. A steady-state model with typical rates of precipitation and evapotranspiration was run to set the initial conditions for the Baldhill Dam Pool Raise simulations. A profile of the ground surface elevation and water table elevation for this model is shown in Figure F-1. Figure F-2 shows hydrographs of water table elevations near the river throughout a typical year without and with the effects of the Devils Lake

Outlet. Figure F-3 shows the differences between such hydrographs at four distances from the river. Figure F-4 shows hydrographs of water table elevations near the river throughout a 100-year flood event without and with the effects of the Baldhill Dam Pool Raise. Figure F-5 shows the differences between such hydrographs at four distances from the river.

In the case of the Baldhill Pool raise simulations, it was not possible to determine the lag time beyond the 100-year flood event because the river stage at the Lisbon gage did not return to the pre-flood stage (see Figure 2). This causes a residual offset from the baseline condition to persist in the simulations that is not time-dependent (see Figure F-4.)

In the case of the Devils Lake outlet simulation, there is a significant time lag in the effects (see Figure F-3). At cross-section 2, the time lag is such that after the outlet stops operation on 30 November, groundwater levels near the Sheyenne River converge toward the baseline elevation, but are estimated to still be about 0.2 foot above the baseline condition when the outlet resumes operation on May 1.

The water table positions at the maximum elevation of the water table for the Baldhill Pool Raise simulation at Cross-section 2 are shown on Figure F-6. As shown on Figure 13 of the main report, the effect of the proposed project is limited to areas near the river. For purposes of comparison, the water table from the steady-state simulation that forms the initial condition for the Baldhill Pool Raise simulation was included on Figure F-6. It can be seen that for all three simulations, the water table position is only affected by changes in the river stage within a few hundred feet of the river. The river stage in each case is equal to the elevation at the right end of the trace representing the water table.

The water table positions at the time of maximum difference in groundwater elevation during the Devils Lake Outlet simulation are shown on Figure F-7. As with the Baldhill Pool Raise simulation, the differences between the two simulations are limited to within a few hundred feet of the river.

Flow Budgets

The overall flow budget report for the steady-state simulation at cross-section 2 is presented in Table F-16. In the steady-state model for this cross-section, no discharge occurs at the drains representing the river valley walls. Fifty-three percent of the water entering the aquifer as recharge exits the aquifer as evapotranspiration and the balance discharges to the river (represented by a constant head cell). The distribution of evapotranspiration across the model is shown on Figure F-8. The rate of evapotranspiration (most negative on Figure F-8) is greatest where the steady-state water level is within 7.2 feet of ground surface; and no evapotranspiration occurs where the water level is more than 11.3 feet below ground surface. Eighty-four percent of the evapotranspiration occurs in the upland area (outside of the river valley).

A zone budget report for the steady-state simulation is presented in Table F-19. Zone 1 in each layer of the model represents the relatively high hydraulic conductivity material and Zone 2 in each layer (where present) represents the relatively low hydraulic conductivity material. The amount of water flowing through the lower hydraulic conductivity material is markedly lower than in the higher conductivity material. This was the intended effect of using the lower hydraulic conductivity zones to represent material beneath the Sheyenne Delta aquifer rather than setting these zones inactive.

The overall flow budget report for the Baldhill Dam Pool Raise simulation and the Devils Lake Outlet simulation at cross-section 2 are presented in Tables F-17 and F-18, respectively. In this cross-section, no discharge was induced at the drain cells representing seepage in the valley walls in either of the transient simulations. In other words, the rate of evapotranspiration was sufficient to prevent the simulated water level from reaching ground surface.

Table F-1   MODFLOW'96 Name File for the Steady State Simulation

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evt 15  xsect2.EVT
rch 18  xsect2.RCH
chd 30  xsect2.CHD
pcg 23  xsect5.PCG
OC  22  xsect2.OPC
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Table F-2   Basic Package Input File in the Steady State Simulation

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R-099	1
R-100	1
R-101	1
R-102	1
R-103	1
R-104	1
R-105	1
R-106	1
R-107	1
R-108	1
R-109	1
R-110	1
R-111	1
R-112	1
R-113	1
R-114	1
R-115	1
R-116	1
R-117	1
R-118	1
R-119	1
R-120	1
R-121	1
R-122	1
R-123	1
R-124	1
R-125	1
R-126	1
R-127	1
R-128	1
R-129	1
R-130	1
R-131	1
R-132	1

```
R-133   1
R-134   1
R-135   1
R-136   1
R-137   1
R-138   1
R-139   1
R-140   1
R-141   1
R-142   1
R-143   1
R-144   1
R-145   1
R-146   1
R-147   1
R-148   1
R-149   1
R-150   1
R-151   1
R-152   1
R-153   1
R-154   1
R-155   1
R-156   1
R-157   1
R-158   1
R-159   1
R-160   1
R-161   1
R-162   1
R-163   1
R-164   1
R-165   1
R-166   1
R-167   1
R-168   1
R-169   1
R-170   1
R-171   1
R-172   1
R-173   1
R-174   1
R-175   1
R-176   1
R-177   1
R-178   1
R-179   1
R-180   1
R-181   1
R-182   1
R-183   1
R-184   1
R-185   1
R-186   1
R-187   1
R-188   1
R-189   1
R-190   1
R-191   1
R-192   1
R-193   1
         0         1                                   */IBOUND        layer: 4
         0         1                                   */IBOUND        layer: 5
         0         1                                   */IBOUND        layer: 6
         0         1                                   */IBOUND        layer: 7
         0         1                                   */IBOUND        layer: 8
```

```
  -999.000
       -90 0.000E+00(6x,10f11.0)               -12   */StartingHead  layer: 1
       -90 0.000E+00(6x,10f11.0)               -12   */StartingHead  layer: 2
       -90 0.000E+00(6x,10f11.0)               -12   */StartingHead  layer: 3
       -90 0.000E+00(6x,10f11.0)               -12   */StartingHead  layer: 4
       -90 0.000E+00(6x,10f11.0)               -12   */StartingHead  layer: 5
       -90 0.000E+00(6x,10f11.0)               -12   */StartingHead  layer: 6
       -90 0.000E+00(6x,10f11.0)               -12   */StartingHead  layer: 7
       -90 0.000E+00(6x,10f11.0)               -12   */StartingHead  layer: 8
1.0000E+00         1      1.000                      */Stress Period:   1
```

Table F-3 Block-centered Flow Package Input File in the Steady State Simulation

```
         1         2 0.100E+31
 1 3 3 3 3 3 0 0
         0 1.000E+00                               */TRPY
         0 1.000E+00                               */DELR
         0 1.450E+01                               */DELC
        11 0.000E+00(6x,10f11.0)             -12   */HY              layer: 1
R-001  7.0008E+00
R-002  7.2068E+00
R-003  7.4138E+00
R-004  7.6199E+00
R-005  7.8269E+00
R-006  8.0350E+00
R-007  8.2410E+00
R-008  8.4480E+00
R-009  8.6541E+00
R-010  8.8611E+00
R-011  9.0679E+00
R-012  9.2799E+00
R-013  9.4911E+00
R-014  9.7021E+00
R-015  9.9113E+00
R-016  1.0106E+01
R-017  1.0221E+01
R-018  1.0335E+01
R-019  1.0446E+01
R-020  1.0556E+01
R-021  1.0666E+01
R-022  1.0777E+01
R-023  1.0882E+01
R-024  1.0987E+01
R-025  1.1091E+01
R-026  1.1197E+01
R-027  1.1302E+01
R-028  1.1417E+01
R-029  1.1537E+01
R-030  1.1657E+01
R-031  1.1778E+01
R-032  1.1898E+01
R-033  1.1993E+01
R-034  1.2046E+01
R-035  1.2099E+01
R-036  1.2152E+01
R-037  1.2207E+01
R-038  1.2262E+01
R-039  1.2315E+01
R-040  1.2365E+01
R-041  1.2414E+01
R-042  1.2464E+01
R-043  1.2514E+01
R-044  1.2564E+01
R-045  1.2613E+01
R-046  1.2661E+01
R-047  1.2710E+01
R-048  1.2758E+01
R-049  1.2802E+01
R-050  1.2832E+01
R-051  1.2861E+01
R-052  1.2891E+01
R-053  1.2920E+01
R-054  1.2938E+01
R-055  1.2957E+01
R-056  1.2975E+01
R-057  1.2993E+01
```

R-058	1.3012E+01
R-059	1.3031E+01
R-060	1.3049E+01
R-061	1.3068E+01
R-062	1.3086E+01
R-063	1.3105E+01
R-064	1.3123E+01
R-065	1.3142E+01
R-066	1.3162E+01
R-067	1.3178E+01
R-068	1.3178E+01
R-069	1.3176E+01
R-070	1.3174E+01
R-071	1.3172E+01
R-072	1.3170E+01
R-073	1.3168E+01
R-074	1.3166E+01
R-075	1.3164E+01
R-076	1.3162E+01
R-077	1.3160E+01
R-078	1.3157E+01
R-079	1.3155E+01
R-080	1.3152E+01
R-081	1.3150E+01
R-082	1.3148E+01
R-083	1.3145E+01
R-084	1.3143E+01
R-085	1.3133E+01
R-086	1.3118E+01
R-087	1.3103E+01
R-088	1.3089E+01
R-089	1.3074E+01
R-090	1.3059E+01
R-091	1.3044E+01
R-092	1.3029E+01
R-093	1.3014E+01
R-094	1.2999E+01
R-095	1.2984E+01
R-096	1.2969E+01
R-097	1.2953E+01
R-098	1.2938E+01
R-099	1.2922E+01
R-100	1.2907E+01
R-101	1.2891E+01
R-102	1.2873E+01
R-103	1.2847E+01
R-104	1.2822E+01
R-105	1.2798E+01
R-106	1.2773E+01
R-107	1.2748E+01
R-108	1.2723E+01
R-109	1.2697E+01
R-110	1.2672E+01
R-111	1.2647E+01
R-112	1.2621E+01
R-113	1.2596E+01
R-114	1.2571E+01
R-115	1.2545E+01
R-116	1.2520E+01
R-117	1.2494E+01
R-118	1.2469E+01
R-119	1.2443E+01
R-120	1.2413E+01
R-121	1.2382E+01
R-122	1.2352E+01
R-123	1.2322E+01

R-124	1.2292E+01
R-125	1.2262E+01
R-126	1.2231E+01
R-127	1.2201E+01
R-128	1.2171E+01
R-129	1.2140E+01
R-130	1.2109E+01
R-131	1.2077E+01
R-132	1.2046E+01
R-133	1.2015E+01
R-134	1.1984E+01
R-135	1.1953E+01
R-136	1.1921E+01
R-137	1.1889E+01
R-138	1.1856E+01
R-139	1.1824E+01
R-140	1.1792E+01
R-141	1.1759E+01
R-142	1.1727E+01
R-143	1.1695E+01
R-144	1.1662E+01
R-145	1.1630E+01
R-146	1.1598E+01
R-147	1.1566E+01
R-148	1.1534E+01
R-149	1.1503E+01
R-150	1.1472E+01
R-151	1.1440E+01
R-152	1.1409E+01
R-153	1.1377E+01
R-154	1.1349E+01
R-155	1.1321E+01
R-156	1.1293E+01
R-157	1.1264E+01
R-158	1.1236E+01
R-159	1.1208E+01
R-160	1.1180E+01
R-161	1.1151E+01
R-162	1.1122E+01
R-163	1.1094E+01
R-164	1.1064E+01
R-165	1.1036E+01
R-166	1.1007E+01
R-167	1.0978E+01
R-168	1.0949E+01
R-169	1.0921E+01
R-170	1.0892E+01
R-171	1.0879E+01
R-172	1.0870E+01
R-173	1.0862E+01
R-174	1.0853E+01
R-175	1.0845E+01
R-176	1.0836E+01
R-177	1.0828E+01
R-178	1.0819E+01
R-179	1.0810E+01
R-180	1.0801E+01
R-181	1.0793E+01
R-182	1.0784E+01
R-183	1.0776E+01
R-184	1.0765E+01
R-185	1.0755E+01
R-186	1.0745E+01
R-187	1.0734E+01
R-188	1.0728E+01
R-189	1.0723E+01

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R-190  1.0718E+01
R-191  1.0714E+01
R-192  1.0710E+01
R-193  1.0707E+01
         0 3.250E+02                                    */BOT            layer: 1
        11 0.000E+00(6x,10f11.0)                  -12   */VCONT          layer: 1
R-001  7.0008E-02
R-002  7.2068E-02
R-003  7.4138E-02
R-004  7.6199E-02
R-005  7.8269E-02
R-006  8.0350E-02
R-007  8.2410E-02
R-008  8.4480E-02
R-009  8.6541E-02
R-010  8.8611E-02
R-011  9.0679E-02
R-012  9.2799E-02
R-013  9.4911E-02
R-014  9.7021E-02
R-015  9.9113E-02
R-016  1.0106E-01
R-017  1.0221E-01
R-018  1.0335E-01
R-019  1.0446E-01
R-020  1.0556E-01
R-021  1.0666E-01
R-022  1.0777E-01
R-023  1.0882E-01
R-024  1.0987E-01
R-025  1.1091E-01
R-026  1.1197E-01
R-027  1.1302E-01
R-028  1.1417E-01
R-029  1.1537E-01
R-030  1.1657E-01
R-031  1.1778E-01
R-032  1.1898E-01
R-033  1.1993E-01
R-034  1.2046E-01
R-035  1.2099E-01
R-036  1.2152E-01
R-037  1.2207E-01
R-038  1.2262E-01
R-039  1.2315E-01
R-040  1.2365E-01
R-041  1.2414E-01
R-042  1.2464E-01
R-043  1.2514E-01
R-044  1.2564E-01
R-045  1.2613E-01
R-046  1.2661E-01
R-047  1.2710E-01
R-048  1.2758E-01
R-049  1.2802E-01
R-050  1.2832E-01
R-051  1.2861E-01
R-052  1.2891E-01
R-053  1.2920E-01
R-054  1.2938E-01
R-055  1.2957E-01
R-056  1.2975E-01
R-057  1.2993E-01
R-058  1.3012E-01
R-059  1.3031E-01
R-060  1.3049E-01
```

R-061	1.3068E-01
R-062	1.3086E-01
R-063	1.3105E-01
R-064	1.3123E-01
R-065	1.3142E-01
R-066	1.3162E-01
R-067	1.3178E-01
R-068	1.3178E-01
R-069	1.3176E-01
R-070	1.3174E-01
R-071	1.3172E-01
R-072	1.3170E-01
R-073	1.3168E-01
R-074	1.3166E-01
R-075	1.3164E-01
R-076	1.3162E-01
R-077	1.3160E-01
R-078	1.3157E-01
R-079	1.3155E-01
R-080	1.3152E-01
R-081	1.3150E-01
R-082	1.3148E-01
R-083	1.3145E-01
R-084	1.3143E-01
R-085	1.3133E-01
R-086	1.3118E-01
R-087	1.3103E-01
R-088	1.3089E-01
R-089	1.3074E-01
R-090	1.3059E-01
R-091	1.3044E-01
R-092	1.3029E-01
R-093	1.3014E-01
R-094	1.2999E-01
R-095	1.2984E-01
R-096	1.2969E-01
R-097	1.2953E-01
R-098	1.2938E-01
R-099	1.2922E-01
R-100	1.2907E-01
R-101	1.2891E-01
R-102	1.2873E-01
R-103	1.2847E-01
R-104	1.2822E-01
R-105	1.2798E-01
R-106	1.2773E-01
R-107	1.2748E-01
R-108	1.2723E-01
R-109	1.2697E-01
R-110	1.2672E-01
R-111	1.2647E-01
R-112	1.2621E-01
R-113	1.2596E-01
R-114	1.2571E-01
R-115	1.2545E-01
R-116	1.2520E-01
R-117	1.2494E-01
R-118	1.2469E-01
R-119	1.2443E-01
R-120	1.2413E-01
R-121	1.2382E-01
R-122	1.2352E-01
R-123	1.2322E-01
R-124	1.2292E-01
R-125	1.2262E-01
R-126	1.2231E-01

R-127	1.2201E-01
R-128	1.2171E-01
R-129	1.2140E-01
R-130	1.2109E-01
R-131	1.2077E-01
R-132	1.2046E-01
R-133	1.2015E-01
R-134	1.1984E-01
R-135	1.1953E-01
R-136	1.1921E-01
R-137	1.1889E-01
R-138	1.1856E-01
R-139	1.1824E-01
R-140	1.1792E-01
R-141	1.1759E-01
R-142	1.1727E-01
R-143	1.1695E-01
R-144	1.1662E-01
R-145	1.1630E-01
R-146	1.1598E-01
R-147	1.1566E-01
R-148	1.1534E-01
R-149	1.1503E-01
R-150	1.1472E-01
R-151	1.1440E-01
R-152	1.1409E-01
R-153	1.1377E-01
R-154	1.1349E-01
R-155	1.1321E-01
R-156	1.1293E-01
R-157	1.1264E-01
R-158	1.1236E-01
R-159	1.1208E-01
R-160	1.1180E-01
R-161	1.1151E-01
R-162	1.1122E-01
R-163	1.1094E-01
R-164	1.1064E-01
R-165	1.1036E-01
R-166	1.1007E-01
R-167	1.0978E-01
R-168	1.0949E-01
R-169	1.0921E-01
R-170	1.0892E-01
R-171	1.0879E-01
R-172	1.0870E-01
R-173	1.0862E-01
R-174	1.0853E-01
R-175	1.0845E-01
R-176	1.0836E-01
R-177	1.0828E-01
R-178	1.0819E-01
R-179	1.0810E-01
R-180	1.0801E-01
R-181	1.0793E-01
R-182	1.0784E-01
R-183	1.0776E-01
R-184	1.0765E-01
R-185	1.0755E-01
R-186	1.0745E-01
R-187	1.0734E-01
R-188	1.0728E-01
R-189	1.0723E-01
R-190	1.0718E-01
R-191	1.0714E-01
R-192	1.0710E-01

R-193	1.0707E-01			
	11 0.000E+00(6x,10f11.0)	-12	*/HY	layer: 2
R-001	7.0008E+00			
R-002	7.2068E+00			
R-003	7.4138E+00			
R-004	7.6199E+00			
R-005	7.8269E+00			
R-006	8.0350E+00			
R-007	8.2410E+00			
R-008	8.4480E+00			
R-009	8.6541E+00			
R-010	8.8611E+00			
R-011	9.0679E+00			
R-012	9.2799E+00			
R-013	9.4911E+00			
R-014	9.7021E+00			
R-015	9.9113E+00			
R-016	1.0106E+01			
R-017	1.0221E+01			
R-018	1.0335E+01			
R-019	1.0446E+01			
R-020	1.0556E+01			
R-021	1.0666E+01			
R-022	1.0777E+01			
R-023	1.0882E+01			
R-024	1.0987E+01			
R-025	1.1091E+01			
R-026	1.1197E+01			
R-027	1.1302E+01			
R-028	1.1417E+01			
R-029	1.1537E+01			
R-030	1.1657E+01			
R-031	1.1778E+01			
R-032	1.1898E+01			
R-033	1.1993E+01			
R-034	1.2046E+01			
R-035	1.2099E+01			
R-036	1.2152E+01			
R-037	1.2207E+01			
R-038	1.2262E+01			
R-039	1.2315E+01			
R-040	1.2365E+01			
R-041	1.2414E+01			
R-042	1.2464E+01			
R-043	1.2514E+01			
R-044	1.2564E+01			
R-045	1.2613E+01			
R-046	1.2661E+01			
R-047	1.2710E+01			
R-048	1.2758E+01			
R-049	1.2802E+01			
R-050	1.2832E+01			
R-051	1.2861E+01			
R-052	1.2891E+01			
R-053	1.2920E+01			
R-054	1.2938E+01			
R-055	1.2957E+01			
R-056	1.2975E+01			
R-057	1.2993E+01			
R-058	1.3012E+01			
R-059	1.3031E+01			
R-060	1.3049E+01			
R-061	1.3068E+01			
R-062	1.3086E+01			
R-063	1.3105E+01			
R-064	1.3123E+01			

R-065	1.3142E+01
R-066	1.3162E+01
R-067	1.3178E+01
R-068	1.3178E+01
R-069	1.3176E+01
R-070	1.3174E+01
R-071	1.3172E+01
R-072	1.3170E+01
R-073	1.3168E+01
R-074	1.3166E+01
R-075	1.3164E+01
R-076	1.3162E+01
R-077	1.3160E+01
R-078	1.3157E+01
R-079	1.3155E+01
R-080	1.3152E+01
R-081	1.3150E+01
R-082	1.3148E+01
R-083	1.3145E+01
R-084	1.3143E+01
R-085	1.3133E+01
R-086	1.3118E+01
R-087	1.3103E+01
R-088	1.3089E+01
R-089	1.3074E+01
R-090	1.3059E+01
R-091	1.3044E+01
R-092	1.3029E+01
R-093	1.3014E+01
R-094	1.2999E+01
R-095	1.2984E+01
R-096	1.2969E+01
R-097	1.2953E+01
R-098	1.2938E+01
R-099	1.2922E+01
R-100	1.2907E+01
R-101	1.2891E+01
R-102	1.2873E+01
R-103	1.2847E+01
R-104	1.2822E+01
R-105	1.2798E+01
R-106	1.2773E+01
R-107	1.2748E+01
R-108	1.2723E+01
R-109	1.2697E+01
R-110	1.2672E+01
R-111	1.2647E+01
R-112	1.2621E+01
R-113	1.2596E+01
R-114	1.2571E+01
R-115	1.2545E+01
R-116	1.2520E+01
R-117	1.2494E+01
R-118	1.2469E+01
R-119	1.2443E+01
R-120	1.2413E+01
R-121	1.2382E+01
R-122	1.2352E+01
R-123	1.2322E+01
R-124	1.2292E+01
R-125	1.2262E+01
R-126	1.2231E+01
R-127	1.2201E+01
R-128	1.2171E+01
R-129	1.2140E+01
R-130	1.2109E+01

```
R-131  1.2077E+01
R-132  1.2046E+01
R-133  1.2015E+01
R-134  1.1984E+01
R-135  1.1953E+01
R-136  1.1921E+01
R-137  1.1889E+01
R-138  1.1856E+01
R-139  1.1824E+01
R-140  1.1792E+01
R-141  1.1759E+01
R-142  1.1727E+01
R-143  1.1695E+01
R-144  1.1662E+01
R-145  1.1630E+01
R-146  1.1598E+01
R-147  1.1566E+01
R-148  1.1534E+01
R-149  1.1503E+01
R-150  1.1472E+01
R-151  1.1440E+01
R-152  1.1409E+01
R-153  1.1377E+01
R-154  1.1349E+01
R-155  1.1321E+01
R-156  1.1293E+01
R-157  1.1264E+01
R-158  1.1236E+01
R-159  1.1208E+01
R-160  1.1180E+01
R-161  1.1151E+01
R-162  1.1122E+01
R-163  1.1094E+01
R-164  1.1064E+01
R-165  1.1036E+01
R-166  1.1007E+01
R-167  1.0978E+01
R-168  1.0949E+01
R-169  1.0921E+01
R-170  1.0892E+01
R-171  1.0879E+01
R-172  1.0870E+01
R-173  1.0862E+01
R-174  1.0853E+01
R-175  1.0845E+01
R-176  1.0836E+01
R-177  1.0828E+01
R-178  1.0819E+01
R-179  1.0810E+01
R-180  1.0801E+01
R-181  1.0793E+01
R-182  1.0784E+01
R-183  1.0776E+01
R-184  1.0765E+01
R-185  1.0755E+01
R-186  1.0745E+01
R-187  1.0734E+01
R-188  1.0728E+01
R-189  1.0723E+01
R-190  1.0718E+01
R-191  1.0714E+01
R-192  1.0710E+01
R-193  1.0707E+01
         0 3.200E+02                               */BOT             layer: 2
        11 0.000E+00(6x,10f11.0)             -12   */VCONT           layer: 2
R-001  2.5457E-01
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R-002	2.6207E-01
R-003	2.6959E-01
R-004	2.7709E-01
R-005	2.8461E-01
R-006	2.9218E-01
R-007	2.9967E-01
R-008	3.0720E-01
R-009	3.1469E-01
R-010	3.2222E-01
R-011	3.2974E-01
R-012	3.3745E-01
R-013	3.4513E-01
R-014	3.5280E-01
R-015	3.6041E-01
R-016	3.6749E-01
R-017	3.7167E-01
R-018	3.7582E-01
R-019	3.7985E-01
R-020	3.8385E-01
R-021	3.8785E-01
R-022	3.9189E-01
R-023	3.9571E-01
R-024	3.9953E-01
R-025	4.0331E-01
R-026	4.0716E-01
R-027	4.1098E-01
R-028	4.1516E-01
R-029	4.1953E-01
R-030	4.2389E-01
R-031	4.2829E-01
R-032	4.3265E-01
R-033	4.3611E-01
R-034	4.3804E-01
R-035	4.3996E-01
R-036	4.4189E-01
R-037	4.4389E-01
R-038	4.4589E-01
R-039	4.4782E-01
R-040	4.4964E-01
R-041	4.5142E-01
R-042	4.5324E-01
R-043	4.5505E-01
R-044	4.5687E-01
R-045	4.5865E-01
R-046	4.6040E-01
R-047	4.6218E-01
R-048	4.6393E-01
R-049	4.6553E-01
R-050	4.6662E-01
R-051	4.6767E-01
R-052	4.6876E-01
R-053	4.6982E-01
R-054	4.7047E-01
R-055	4.7116E-01
R-056	4.7182E-01
R-057	4.7247E-01
R-058	4.7316E-01
R-059	4.7385E-01
R-060	4.7451E-01
R-061	4.7520E-01
R-062	4.7585E-01
R-063	4.7655E-01
R-064	4.7720E-01
R-065	4.7789E-01
R-066	4.7862E-01
R-067	4.7920E-01

R-068	4.7920E-01
R-069	4.7913E-01
R-070	4.7905E-01
R-071	4.7898E-01
R-072	4.7891E-01
R-073	4.7884E-01
R-074	4.7876E-01
R-075	4.7869E-01
R-076	4.7862E-01
R-077	4.7855E-01
R-078	4.7844E-01
R-079	4.7836E-01
R-080	4.7825E-01
R-081	4.7818E-01
R-082	4.7811E-01
R-083	4.7800E-01
R-084	4.7793E-01
R-085	4.7756E-01
R-086	4.7702E-01
R-087	4.7647E-01
R-088	4.7596E-01
R-089	4.7542E-01
R-090	4.7487E-01
R-091	4.7433E-01
R-092	4.7378E-01
R-093	4.7324E-01
R-094	4.7269E-01
R-095	4.7215E-01
R-096	4.7160E-01
R-097	4.7102E-01
R-098	4.7047E-01
R-099	4.6989E-01
R-100	4.6935E-01
R-101	4.6876E-01
R-102	4.6811E-01
R-103	4.6716E-01
R-104	4.6625E-01
R-105	4.6538E-01
R-106	4.6447E-01
R-107	4.6356E-01
R-108	4.0871E-02
R-109	4.0864E-02
R-110	4.0858E-02
R-111	4.0851E-02
R-112	4.0845E-02
R-113	4.0838E-02
R-114	4.0831E-02
R-115	4.0825E-02
R-116	4.0818E-02
R-117	4.0811E-02
R-118	4.0804E-02
R-119	4.0797E-02
R-120	4.0789E-02
R-121	4.0781E-02
R-122	4.0773E-02
R-123	4.0765E-02
R-124	4.0756E-02
R-125	4.0748E-02
R-126	4.0739E-02
R-127	4.4367E-01
R-128	4.4258E-01
R-129	4.4145E-01
R-130	4.4033E-01
R-131	4.3916E-01
R-132	4.3804E-01
R-133	4.3691E-01

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R-134  4.3578E-01
R-135  4.3465E-01
R-136  4.3349E-01
R-137  4.3233E-01
R-138  4.3113E-01
R-139  4.2996E-01
R-140  4.2880E-01
R-141  4.2760E-01
R-142  4.2644E-01
R-143  4.2527E-01
R-144  4.2407E-01
R-145  4.2291E-01
R-146  4.2175E-01
R-147  4.2058E-01
R-148  4.1942E-01
R-149  4.1829E-01
R-150  4.1716E-01
R-151  4.1600E-01
R-152  4.1487E-01
R-153  4.1371E-01
R-154  4.1269E-01
R-155  4.1167E-01
R-156  4.1065E-01
R-157  4.0960E-01
R-158  4.0858E-01
R-159  4.0756E-01
R-160  4.0655E-01
R-161  4.0549E-01
R-162  4.0444E-01
R-163  4.0342E-01
R-164  4.0233E-01
R-165  4.0131E-01
R-166  4.0025E-01
R-167  3.9920E-01
R-168  3.9815E-01
R-169  3.9713E-01
R-170  3.9607E-01
R-171  3.7101E-01
R-172  2.1740E-01
R-173  2.1724E-01
R-174  2.1706E-01
R-175  2.1690E-01
R-176  2.1672E-01
R-177  2.1656E-01
R-178  2.1638E-01
R-179  2.1620E-01
R-180  2.1602E-01
R-181  2.1586E-01
R-182  2.1568E-01
R-183  2.1552E-01
R-184  2.1530E-01
R-185  2.1510E-01
R-186  2.1490E-01
R-187  2.1468E-01
R-188  2.1456E-01
R-189  2.1446E-01
R-190  2.1436E-01
R-191  2.1428E-01
R-192  2.1420E-01
R-193  2.1414E-01
        0 3.250E+02                             */TOP            layer: 2
       11 0.000E+00(6x,10f11.0)           -12   */HY             layer: 3
R-001  7.0008E+00
R-002  7.2068E+00
R-003  7.4138E+00
R-004  7.6199E+00
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R-005	7.8269E+00
R-006	8.0350E+00
R-007	8.2410E+00
R-008	8.4480E+00
R-009	8.6541E+00
R-010	8.8611E+00
R-011	9.0679E+00
R-012	9.2799E+00
R-013	9.4911E+00
R-014	9.7021E+00
R-015	9.9113E+00
R-016	1.0106E+01
R-017	1.0221E+01
R-018	1.0335E+01
R-019	1.0446E+01
R-020	1.0556E+01
R-021	1.0666E+01
R-022	1.0777E+01
R-023	1.0882E+01
R-024	1.0987E+01
R-025	1.1091E+01
R-026	1.1197E+01
R-027	1.1302E+01
R-028	1.1417E+01
R-029	1.1537E+01
R-030	1.1657E+01
R-031	1.1778E+01
R-032	1.1898E+01
R-033	1.1993E+01
R-034	1.2046E+01
R-035	1.2099E+01
R-036	1.2152E+01
R-037	1.2207E+01
R-038	1.2262E+01
R-039	1.2315E+01
R-040	1.2365E+01
R-041	1.2414E+01
R-042	1.2464E+01
R-043	1.2514E+01
R-044	1.2564E+01
R-045	1.2613E+01
R-046	1.2661E+01
R-047	1.2710E+01
R-048	1.2758E+01
R-049	1.2802E+01
R-050	1.2832E+01
R-051	1.2861E+01
R-052	1.2891E+01
R-053	1.2920E+01
R-054	1.2938E+01
R-055	1.2957E+01
R-056	1.2975E+01
R-057	1.2993E+01
R-058	1.3012E+01
R-059	1.3031E+01
R-060	1.3049E+01
R-061	1.3068E+01
R-062	1.3086E+01
R-063	1.3105E+01
R-064	1.3123E+01
R-065	1.3142E+01
R-066	1.3162E+01
R-067	1.3178E+01
R-068	1.3178E+01
R-069	1.3176E+01
R-070	1.3174E+01

R-071	1.3172E+01
R-072	1.3170E+01
R-073	1.3168E+01
R-074	1.3166E+01
R-075	1.3164E+01
R-076	1.3162E+01
R-077	1.3160E+01
R-078	1.3157E+01
R-079	1.3155E+01
R-080	1.3152E+01
R-081	1.3150E+01
R-082	1.3148E+01
R-083	1.3145E+01
R-084	1.3143E+01
R-085	1.3133E+01
R-086	1.3118E+01
R-087	1.3103E+01
R-088	1.3089E+01
R-089	1.3074E+01
R-090	1.3059E+01
R-091	1.3044E+01
R-092	1.3029E+01
R-093	1.3014E+01
R-094	1.2999E+01
R-095	1.2984E+01
R-096	1.2969E+01
R-097	1.2953E+01
R-098	1.2938E+01
R-099	1.2922E+01
R-100	1.2907E+01
R-101	1.2891E+01
R-102	1.2873E+01
R-103	1.2847E+01
R-104	1.2822E+01
R-105	1.2798E+01
R-106	1.2773E+01
R-107	1.2748E+01
R-108	1.1110E-01
R-109	1.1110E-01
R-110	1.1110E-01
R-111	1.1110E-01
R-112	1.1110E-01
R-113	1.1110E-01
R-114	1.1110E-01
R-115	1.1110E-01
R-116	1.1110E-01
R-117	1.1110E-01
R-118	1.1110E-01
R-119	1.1110E-01
R-120	1.1110E-01
R-121	1.1110E-01
R-122	1.1110E-01
R-123	1.1110E-01
R-124	1.1110E-01
R-125	1.1110E-01
R-126	1.1110E-01
R-127	1.2201E+01
R-128	1.2171E+01
R-129	1.2140E+01
R-130	1.2109E+01
R-131	1.2077E+01
R-132	1.2046E+01
R-133	1.2015E+01
R-134	1.1984E+01
R-135	1.1953E+01
R-136	1.1921E+01

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R-137  1.1889E+01
R-138  1.1856E+01
R-139  1.1824E+01
R-140  1.1792E+01
R-141  1.1759E+01
R-142  1.1727E+01
R-143  1.1695E+01
R-144  1.1662E+01
R-145  1.1630E+01
R-146  1.1598E+01
R-147  1.1566E+01
R-148  1.1534E+01
R-149  1.1503E+01
R-150  1.1472E+01
R-151  1.1440E+01
R-152  1.1409E+01
R-153  1.1377E+01
R-154  1.1349E+01
R-155  1.1321E+01
R-156  1.1293E+01
R-157  1.1264E+01
R-158  1.1236E+01
R-159  1.1208E+01
R-160  1.1180E+01
R-161  1.1151E+01
R-162  1.1122E+01
R-163  1.1094E+01
R-164  1.1064E+01
R-165  1.1036E+01
R-166  1.1007E+01
R-167  1.0978E+01
R-168  1.0949E+01
R-169  1.0921E+01
R-170  1.0892E+01
R-171  1.0879E+01
R-172  1.0870E+01
R-173  1.0862E+01
R-174  1.0853E+01
R-175  1.0845E+01
R-176  1.0836E+01
R-177  1.0828E+01
R-178  1.0819E+01
R-179  1.0810E+01
R-180  1.0801E+01
R-181  1.0793E+01
R-182  1.0784E+01
R-183  1.0776E+01
R-184  1.0765E+01
R-185  1.0755E+01
R-186  1.0745E+01
R-187  1.0734E+01
R-188  1.0728E+01
R-189  1.0723E+01
R-190  1.0718E+01
R-191  1.0714E+01
R-192  1.0710E+01
R-193  1.0707E+01
          0 3.150E+02                              */BOT           layer: 3
         11 0.000E+00(6x,10f11.0)            -12   */VCONT         layer: 3
R-001  1.4002E+00
R-002  1.4414E+00
R-003  1.4828E+00
R-004  1.5240E+00
R-005  1.5654E+00
R-006  1.6070E+00
R-007  1.6482E+00
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R-008	1.6896E+00
R-009	1.7308E+00
R-010	1.7722E+00
R-011	1.8136E+00
R-012	1.8560E+00
R-013	1.8982E+00
R-014	1.9404E+00
R-015	1.9823E+00
R-016	2.0212E+00
R-017	2.0442E+00
R-018	2.0670E+00
R-019	2.0892E+00
R-020	2.1112E+00
R-021	2.1332E+00
R-022	2.1554E+00
R-023	2.1764E+00
R-024	2.1974E+00
R-025	2.2182E+00
R-026	2.2394E+00
R-027	2.2604E+00
R-028	2.2834E+00
R-029	2.3074E+00
R-030	2.3314E+00
R-031	2.3556E+00
R-032	2.3796E+00
R-033	2.3986E+00
R-034	2.4092E+00
R-035	2.4198E+00
R-036	2.4304E+00
R-037	2.4414E+00
R-038	2.4524E+00
R-039	2.4630E+00
R-040	2.4730E+00
R-041	2.4828E+00
R-042	2.4928E+00
R-043	2.5028E+00
R-044	2.5128E+00
R-045	4.4052E-02
R-046	4.4053E-02
R-047	4.4055E-02
R-048	4.4056E-02
R-049	4.4058E-02
R-050	4.4059E-02
R-051	4.4059E-02
R-052	4.4060E-02
R-053	4.4061E-02
R-054	4.4062E-02
R-055	4.4062E-02
R-056	4.4063E-02
R-057	4.4063E-02
R-058	4.4064E-02
R-059	4.4064E-02
R-060	4.4065E-02
R-061	4.4065E-02
R-062	4.4066E-02
R-063	4.4066E-02
R-064	4.4067E-02
R-065	4.4067E-02
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R-067	4.4068E-02
R-068	4.4068E-02
R-069	4.4068E-02
R-070	4.4068E-02
R-071	4.4068E-02
R-072	4.4068E-02
R-073	4.4068E-02

R-074	4.4068E-02
R-075	4.4068E-02
R-076	4.4068E-02
R-077	4.4068E-02
R-078	4.4068E-02
R-079	4.4068E-02
R-080	4.4068E-02
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R-089	4.4066E-02
R-090	4.4065E-02
R-091	4.4065E-02
R-092	4.4064E-02
R-093	4.4064E-02
R-094	4.4063E-02
R-095	4.4063E-02
R-096	4.4063E-02
R-097	4.4062E-02
R-098	4.4062E-02
R-099	4.4061E-02
R-100	4.4061E-02
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R-102	4.4060E-02
R-103	4.4059E-02
R-104	4.4058E-02
R-105	4.4058E-02
R-106	4.4057E-02
R-107	4.4056E-02
R-108	2.2220E-02
R-109	2.2220E-02
R-110	2.2220E-02
R-111	2.2220E-02
R-112	2.2220E-02
R-113	2.2220E-02
R-114	2.2220E-02
R-115	2.2220E-02
R-116	2.2220E-02
R-117	2.2220E-02
R-118	2.2220E-02
R-119	2.2220E-02
R-120	2.2220E-02
R-121	2.2220E-02
R-122	2.2220E-02
R-123	2.2220E-02
R-124	2.2220E-02
R-125	2.2220E-02
R-126	2.2220E-02
R-127	4.4039E-02
R-128	4.4038E-02
R-129	4.4037E-02
R-130	4.4036E-02
R-131	4.4035E-02
R-132	4.4034E-02
R-133	4.4033E-02
R-134	4.4032E-02
R-135	4.4031E-02
R-136	4.4030E-02
R-137	4.4029E-02
R-138	4.4027E-02
R-139	4.4026E-02

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R-140  4.4025E-02
R-141  4.4024E-02
R-142  4.4023E-02
R-143  4.4022E-02
R-144  4.4021E-02
R-145  4.4019E-02
R-146  4.4018E-02
R-147  4.4017E-02
R-148  4.4016E-02
R-149  4.4015E-02
R-150  4.4014E-02
R-151  4.4013E-02
R-152  4.4011E-02
R-153  4.4010E-02
R-154  4.4009E-02
R-155  4.4008E-02
R-156  4.4007E-02
R-157  4.4006E-02
R-158  4.4005E-02
R-159  4.4004E-02
R-160  4.4003E-02
R-161  4.4002E-02
R-162  4.4000E-02
R-163  4.3999E-02
R-164  4.3998E-02
R-165  4.3997E-02
R-166  4.3996E-02
R-167  4.3995E-02
R-168  4.3994E-02
R-169  4.3992E-02
R-170  4.3991E-02
R-171  2.5442E-02
R-172  4.3990E-03
R-173  4.3990E-03
R-174  4.3990E-03
R-175  4.3989E-03
R-176  4.3989E-03
R-177  4.3989E-03
R-178  4.3988E-03
R-179  4.3988E-03
R-180  4.3988E-03
R-181  4.3987E-03
R-182  4.3987E-03
R-183  4.3987E-03
R-184  4.3986E-03
R-185  4.3986E-03
R-186  4.3985E-03
R-187  4.3985E-03
R-188  4.3984E-03
R-189  4.3984E-03
R-190  4.3984E-03
R-191  4.3984E-03
R-192  4.3984E-03
R-193  4.3984E-03
          0 3.200E+02                              */TOP          layer: 3
         11 0.000E+00(6x,10f11.0)            -12   */HY           layer: 4
R-001  7.0008E+00
R-002  7.2068E+00
R-003  7.4138E+00
R-004  7.6199E+00
R-005  7.8269E+00
R-006  8.0350E+00
R-007  8.2410E+00
R-008  8.4480E+00
R-009  8.6541E+00
R-010  8.8611E+00
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R-011	9.0679E+00
R-012	9.2799E+00
R-013	9.4911E+00
R-014	9.7021E+00
R-015	9.9113E+00
R-016	1.0106E+01
R-017	1.0221E+01
R-018	1.0335E+01
R-019	1.0446E+01
R-020	1.0556E+01
R-021	1.0666E+01
R-022	1.0777E+01
R-023	1.0882E+01
R-024	1.0987E+01
R-025	1.1091E+01
R-026	1.1197E+01
R-027	1.1302E+01
R-028	1.1417E+01
R-029	1.1537E+01
R-030	1.1657E+01
R-031	1.1778E+01
R-032	1.1898E+01
R-033	1.1993E+01
R-034	1.2046E+01
R-035	1.2099E+01
R-036	1.2152E+01
R-037	1.2207E+01
R-038	1.2262E+01
R-039	1.2315E+01
R-040	1.2365E+01
R-041	1.2414E+01
R-042	1.2464E+01
R-043	1.2514E+01
R-044	1.2564E+01
R-045	1.1110E-01
R-046	1.1110E-01
R-047	1.1110E-01
R-048	1.1110E-01
R-049	1.1110E-01
R-050	1.1110E-01
R-051	1.1110E-01
R-052	1.1110E-01
R-053	1.1110E-01
R-054	1.1110E-01
R-055	1.1110E-01
R-056	1.1110E-01
R-057	1.1110E-01
R-058	1.1110E-01
R-059	1.1110E-01
R-060	1.1110E-01
R-061	1.1110E-01
R-062	1.1110E-01
R-063	1.1110E-01
R-064	1.1110E-01
R-065	1.1110E-01
R-066	1.1110E-01
R-067	1.1110E-01
R-068	1.1110E-01
R-069	1.1110E-01
R-070	1.1110E-01
R-071	1.1110E-01
R-072	1.1110E-01
R-073	1.1110E-01
R-074	1.1110E-01
R-075	1.1110E-01
R-076	1.1110E-01

R-077	1.1110E-01
R-078	1.1110E-01
R-079	1.1110E-01
R-080	1.1110E-01
R-081	1.1110E-01
R-082	1.1110E-01
R-083	1.1110E-01
R-084	1.1110E-01
R-085	1.1110E-01
R-086	1.1110E-01
R-087	1.1110E-01
R-088	1.1110E-01
R-089	1.1110E-01
R-090	1.1110E-01
R-091	1.1110E-01
R-092	1.1110E-01
R-093	1.1110E-01
R-094	1.1110E-01
R-095	1.1110E-01
R-096	1.1110E-01
R-097	1.1110E-01
R-098	1.1110E-01
R-099	1.1110E-01
R-100	1.1110E-01
R-101	1.1110E-01
R-102	1.1110E-01
R-103	1.1110E-01
R-104	1.1110E-01
R-105	1.1110E-01
R-106	1.1110E-01
R-107	1.1110E-01
R-108	1.1110E-01
R-109	1.1110E-01
R-110	1.1110E-01
R-111	1.1110E-01
R-112	1.1110E-01
R-113	1.1110E-01
R-114	1.1110E-01
R-115	1.1110E-01
R-116	1.1110E-01
R-117	1.1110E-01
R-118	1.1110E-01
R-119	1.1110E-01
R-120	1.1110E-01
R-121	1.1110E-01
R-122	1.1110E-01
R-123	1.1110E-01
R-124	1.1110E-01
R-125	1.1110E-01
R-126	1.1110E-01
R-127	1.1110E-01
R-128	1.1110E-01
R-129	1.1110E-01
R-130	1.1110E-01
R-131	1.1110E-01
R-132	1.1110E-01
R-133	1.1110E-01
R-134	1.1110E-01
R-135	1.1110E-01
R-136	1.1110E-01
R-137	1.1110E-01
R-138	1.1110E-01
R-139	1.1110E-01
R-140	1.1110E-01
R-141	1.1110E-01
R-142	1.1110E-01

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R-143  1.1110E-01
R-144  1.1110E-01
R-145  1.1110E-01
R-146  1.1110E-01
R-147  1.1110E-01
R-148  1.1110E-01
R-149  1.1110E-01
R-150  1.1110E-01
R-151  1.1110E-01
R-152  1.1110E-01
R-153  1.1110E-01
R-154  1.1110E-01
R-155  1.1110E-01
R-156  1.1110E-01
R-157  1.1110E-01
R-158  1.1110E-01
R-159  1.1110E-01
R-160  1.1110E-01
R-161  1.1110E-01
R-162  1.1110E-01
R-163  1.1110E-01
R-164  1.1110E-01
R-165  1.1110E-01
R-166  1.1110E-01
R-167  1.1110E-01
R-168  1.1110E-01
R-169  1.1110E-01
R-170  1.1110E-01
R-171  1.1110E-01
R-172  1.1110E-01
R-173  1.1110E-01
R-174  1.1110E-01
R-175  1.1110E-01
R-176  1.1110E-01
R-177  1.1110E-01
R-178  1.1110E-01
R-179  1.1110E-01
R-180  1.1110E-01
R-181  1.1110E-01
R-182  1.1110E-01
R-183  1.1110E-01
R-184  1.1110E-01
R-185  1.1110E-01
R-186  1.1110E-01
R-187  1.1110E-01
R-188  1.1110E-01
R-189  1.1110E-01
R-190  1.1110E-01
R-191  1.1110E-01
R-192  1.1110E-01
R-193  1.1110E-01
         0 3.100E+02                              */BOT           layer: 4
        11 0.000E+00(6x,10f11.0)            -12   */VCONT         layer: 4
R-001  2.5457E-01
R-002  2.6207E-01
R-003  2.6959E-01
R-004  2.7709E-01
R-005  2.8461E-01
R-006  2.9218E-01
R-007  2.9967E-01
R-008  3.0720E-01
R-009  3.1469E-01
R-010  3.2222E-01
R-011  3.2974E-01
R-012  3.3745E-01
R-013  3.4513E-01
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R-014	3.5280E-01
R-015	3.6041E-01
R-016	3.6749E-01
R-017	3.7167E-01
R-018	4.4392E-03
R-019	4.4393E-03
R-020	4.4393E-03
R-021	4.4394E-03
R-022	4.4394E-03
R-023	4.4395E-03
R-024	4.4395E-03
R-025	4.4396E-03
R-026	4.4396E-03
R-027	4.4396E-03
R-028	4.4397E-03
R-029	4.4397E-03
R-030	4.4398E-03
R-031	4.4398E-03
R-032	4.4399E-03
R-033	4.4399E-03
R-034	4.4399E-03
R-035	4.4399E-03
R-036	4.4399E-03
R-037	4.4400E-03
R-038	4.4400E-03
R-039	4.4400E-03
R-040	4.4400E-03
R-041	4.4400E-03
R-042	4.4400E-03
R-043	4.4401E-03
R-044	4.4401E-03
R-045	4.0400E-03
R-046	4.0400E-03
R-047	4.0400E-03
R-048	4.0400E-03
R-049	4.0400E-03
R-050	4.0400E-03
R-051	4.0400E-03
R-052	4.0400E-03
R-053	4.0400E-03
R-054	4.0400E-03
R-055	4.0400E-03
R-056	4.0400E-03
R-057	4.0400E-03
R-058	4.0400E-03
R-059	4.0400E-03
R-060	4.0400E-03
R-061	4.0400E-03
R-062	4.0400E-03
R-063	4.0400E-03
R-064	4.0400E-03
R-065	4.0400E-03
R-066	4.0400E-03
R-067	4.0400E-03
R-068	4.0400E-03
R-069	4.0400E-03
R-070	4.0400E-03
R-071	4.0400E-03
R-072	4.0400E-03
R-073	4.0400E-03
R-074	4.0400E-03
R-075	4.0400E-03
R-076	4.0400E-03
R-077	4.0400E-03
R-078	4.0400E-03
R-079	4.0400E-03

R-080	4.0400E-03
R-081	4.0400E-03
R-082	4.0400E-03
R-083	4.0400E-03
R-084	4.0400E-03
R-085	4.0400E-03
R-086	4.0400E-03
R-087	4.0400E-03
R-088	4.0400E-03
R-089	4.0400E-03
R-090	4.0400E-03
R-091	4.0400E-03
R-092	4.0400E-03
R-093	4.0400E-03
R-094	4.0400E-03
R-095	4.0400E-03
R-096	4.0400E-03
R-097	4.0400E-03
R-098	4.0400E-03
R-099	4.0400E-03
R-100	4.0400E-03
R-101	4.0400E-03
R-102	4.0400E-03
R-103	4.0400E-03
R-104	4.0400E-03
R-105	4.0400E-03
R-106	4.0400E-03
R-107	4.0400E-03
R-108	4.0400E-03
R-109	4.0400E-03
R-110	4.0400E-03
R-111	4.0400E-03
R-112	4.0400E-03
R-113	4.0400E-03
R-114	4.0400E-03
R-115	4.0400E-03
R-116	4.0400E-03
R-117	4.0400E-03
R-118	4.0400E-03
R-119	4.0400E-03
R-120	4.0400E-03
R-121	4.0400E-03
R-122	4.0400E-03
R-123	4.0400E-03
R-124	4.0400E-03
R-125	4.0400E-03
R-126	4.0400E-03
R-127	4.0400E-03
R-128	4.0400E-03
R-129	4.0400E-03
R-130	4.0400E-03
R-131	4.0400E-03
R-132	4.0400E-03
R-133	4.0400E-03
R-134	4.0400E-03
R-135	4.0400E-03
R-136	4.0400E-03
R-137	4.0400E-03
R-138	4.0400E-03
R-139	4.0400E-03
R-140	4.0400E-03
R-141	4.0400E-03
R-142	4.0400E-03
R-143	4.0400E-03
R-144	4.0400E-03
R-145	4.0400E-03

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R-146  4.0400E-03
R-147  4.0400E-03
R-148  4.0400E-03
R-149  4.0400E-03
R-150  4.0400E-03
R-151  4.0400E-03
R-152  4.0400E-03
R-153  4.0400E-03
R-154  4.0400E-03
R-155  4.0400E-03
R-156  4.0400E-03
R-157  4.0400E-03
R-158  4.0400E-03
R-159  4.0400E-03
R-160  4.0400E-03
R-161  4.0400E-03
R-162  4.0400E-03
R-163  4.0400E-03
R-164  4.0400E-03
R-165  4.0400E-03
R-166  4.0400E-03
R-167  4.0400E-03
R-168  4.0400E-03
R-169  4.0400E-03
R-170  4.0400E-03
R-171  3.7889E-03
R-172  2.2220E-03
R-173  2.2220E-03
R-174  2.2220E-03
R-175  2.2220E-03
R-176  2.2220E-03
R-177  2.2220E-03
R-178  2.2220E-03
R-179  2.2220E-03
R-180  2.2220E-03
R-181  2.2220E-03
R-182  2.2220E-03
R-183  2.2220E-03
R-184  2.2220E-03
R-185  2.2220E-03
R-186  2.2220E-03
R-187  2.2220E-03
R-188  2.2220E-03
R-189  2.2220E-03
R-190  2.2220E-03
R-191  2.2220E-03
R-192  2.2220E-03
R-193  2.2220E-03
         0 3.150E+02                          */TOP          layer: 4
        11 0.000E+00(6x,10f11.0)         -12  */HY           layer: 5
R-001  7.0008E+00
R-002  7.2068E+00
R-003  7.4138E+00
R-004  7.6199E+00
R-005  7.8269E+00
R-006  8.0350E+00
R-007  8.2410E+00
R-008  8.4480E+00
R-009  8.6541E+00
R-010  8.8611E+00
R-011  9.0679E+00
R-012  9.2799E+00
R-013  9.4911E+00
R-014  9.7021E+00
R-015  9.9113E+00
R-016  1.0106E+01
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R-017	1.0221E+01
R-018	1.1110E-01
R-019	1.1110E-01
R-020	1.1110E-01
R-021	1.1110E-01
R-022	1.1110E-01
R-023	1.1110E-01
R-024	1.1110E-01
R-025	1.1110E-01
R-026	1.1110E-01
R-027	1.1110E-01
R-028	1.1110E-01
R-029	1.1110E-01
R-030	1.1110E-01
R-031	1.1110E-01
R-032	1.1110E-01
R-033	1.1110E-01
R-034	1.1110E-01
R-035	1.1110E-01
R-036	1.1110E-01
R-037	1.1110E-01
R-038	1.1110E-01
R-039	1.1110E-01
R-040	1.1110E-01
R-041	1.1110E-01
R-042	1.1110E-01
R-043	1.1110E-01
R-044	1.1110E-01
R-045	1.1110E-01
R-046	1.1110E-01
R-047	1.1110E-01
R-048	1.1110E-01
R-049	1.1110E-01
R-050	1.1110E-01
R-051	1.1110E-01
R-052	1.1110E-01
R-053	1.1110E-01
R-054	1.1110E-01
R-055	1.1110E-01
R-056	1.1110E-01
R-057	1.1110E-01
R-058	1.1110E-01
R-059	1.1110E-01
R-060	1.1110E-01
R-061	1.1110E-01
R-062	1.1110E-01
R-063	1.1110E-01
R-064	1.1110E-01
R-065	1.1110E-01
R-066	1.1110E-01
R-067	1.1110E-01
R-068	1.1110E-01
R-069	1.1110E-01
R-070	1.1110E-01
R-071	1.1110E-01
R-072	1.1110E-01
R-073	1.1110E-01
R-074	1.1110E-01
R-075	1.1110E-01
R-076	1.1110E-01
R-077	1.1110E-01
R-078	1.1110E-01
R-079	1.1110E-01
R-080	1.1110E-01
R-081	1.1110E-01
R-082	1.1110E-01

R-083	1.1110E-01
R-084	1.1110E-01
R-085	1.1110E-01
R-086	1.1110E-01
R-087	1.1110E-01
R-088	1.1110E-01
R-089	1.1110E-01
R-090	1.1110E-01
R-091	1.1110E-01
R-092	1.1110E-01
R-093	1.1110E-01
R-094	1.1110E-01
R-095	1.1110E-01
R-096	1.1110E-01
R-097	1.1110E-01
R-098	1.1110E-01
R-099	1.1110E-01
R-100	1.1110E-01
R-101	1.1110E-01
R-102	1.1110E-01
R-103	1.1110E-01
R-104	1.1110E-01
R-105	1.1110E-01
R-106	1.1110E-01
R-107	1.1110E-01
R-108	1.1110E-01
R-109	1.1110E-01
R-110	1.1110E-01
R-111	1.1110E-01
R-112	1.1110E-01
R-113	1.1110E-01
R-114	1.1110E-01
R-115	1.1110E-01
R-116	1.1110E-01
R-117	1.1110E-01
R-118	1.1110E-01
R-119	1.1110E-01
R-120	1.1110E-01
R-121	1.1110E-01
R-122	1.1110E-01
R-123	1.1110E-01
R-124	1.1110E-01
R-125	1.1110E-01
R-126	1.1110E-01
R-127	1.1110E-01
R-128	1.1110E-01
R-129	1.1110E-01
R-130	1.1110E-01
R-131	1.1110E-01
R-132	1.1110E-01
R-133	1.1110E-01
R-134	1.1110E-01
R-135	1.1110E-01
R-136	1.1110E-01
R-137	1.1110E-01
R-138	1.1110E-01
R-139	1.1110E-01
R-140	1.1110E-01
R-141	1.1110E-01
R-142	1.1110E-01
R-143	1.1110E-01
R-144	1.1110E-01
R-145	1.1110E-01
R-146	1.1110E-01
R-147	1.1110E-01
R-148	1.1110E-01

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R-149  1.1110E-01
R-150  1.1110E-01
R-151  1.1110E-01
R-152  1.1110E-01
R-153  1.1110E-01
R-154  1.1110E-01
R-155  1.1110E-01
R-156  1.1110E-01
R-157  1.1110E-01
R-158  1.1110E-01
R-159  1.1110E-01
R-160  1.1110E-01
R-161  1.1110E-01
R-162  1.1110E-01
R-163  1.1110E-01
R-164  1.1110E-01
R-165  1.1110E-01
R-166  1.1110E-01
R-167  1.1110E-01
R-168  1.1110E-01
R-169  1.1110E-01
R-170  1.1110E-01
R-171  1.1110E-01
R-172  1.1110E-01
R-173  1.1110E-01
R-174  1.1110E-01
R-175  1.1110E-01
R-176  1.1110E-01
R-177  1.1110E-01
R-178  1.1110E-01
R-179  1.1110E-01
R-180  1.1110E-01
R-181  1.1110E-01
R-182  1.1110E-01
R-183  1.1110E-01
R-184  1.1110E-01
R-185  1.1110E-01
R-186  1.1110E-01
R-187  1.1110E-01
R-188  1.1110E-01
R-189  1.1110E-01
R-190  1.1110E-01
R-191  1.1110E-01
R-192  1.1110E-01
R-193  1.1110E-01
         0 3.050E+02                                */BOT            layer: 5
        11 0.000E+00(6x,10f11.0)              -12   */VCONT          layer: 5
R-001  4.3746E-03
R-002  4.3765E-03
R-003  4.3784E-03
R-004  4.3801E-03
R-005  4.3818E-03
R-006  4.3834E-03
R-007  4.3849E-03
R-008  4.3863E-03
R-009  4.3877E-03
R-010  4.3890E-03
R-011  4.3902E-03
R-012  4.3914E-03
R-013  4.3926E-03
R-014  4.3937E-03
R-015  4.3947E-03
R-016  4.3957E-03
R-017  4.3962E-03
R-018  2.2220E-03
R-019  2.2220E-03
```

R-020	2.2220E-03
R-021	2.2220E-03
R-022	2.2220E-03
R-023	2.2220E-03
R-024	2.2220E-03
R-025	2.2220E-03
R-026	2.2220E-03
R-027	2.2220E-03
R-028	2.2220E-03
R-029	2.2220E-03
R-030	2.2220E-03
R-031	2.2220E-03
R-032	2.2220E-03
R-033	2.2220E-03
R-034	2.2220E-03
R-035	2.2220E-03
R-036	2.2220E-03
R-037	2.2220E-03
R-038	2.2220E-03
R-039	2.2220E-03
R-040	2.2220E-03
R-041	2.2220E-03
R-042	2.2220E-03
R-043	2.2220E-03
R-044	2.2220E-03
R-045	2.2220E-03
R-046	2.2220E-03
R-047	2.2220E-03
R-048	2.2220E-03
R-049	2.2220E-03
R-050	2.2220E-03
R-051	2.2220E-03
R-052	2.2220E-03
R-053	2.2220E-03
R-054	2.2220E-03
R-055	2.2220E-03
R-056	2.2220E-03
R-057	2.2220E-03
R-058	2.2220E-03
R-059	2.2220E-03
R-060	2.2220E-03
R-061	2.2220E-03
R-062	2.2220E-03
R-063	2.2220E-03
R-064	2.2220E-03
R-065	2.2220E-03
R-066	2.2220E-03
R-067	2.2220E-03
R-068	2.2220E-03
R-069	2.2220E-03
R-070	2.2220E-03
R-071	2.2220E-03
R-072	2.2220E-03
R-073	2.2220E-03
R-074	2.2220E-03
R-075	2.2220E-03
R-076	2.2220E-03
R-077	2.2220E-03
R-078	2.2220E-03
R-079	2.2220E-03
R-080	2.2220E-03
R-081	2.2220E-03
R-082	2.2220E-03
R-083	2.2220E-03
R-084	2.2220E-03
R-085	2.2220E-03

R-086	2.2220E-03
R-087	2.2220E-03
R-088	2.2220E-03
R-089	2.2220E-03
R-090	2.2220E-03
R-091	2.2220E-03
R-092	2.2220E-03
R-093	2.2220E-03
R-094	2.2220E-03
R-095	2.2220E-03
R-096	2.2220E-03
R-097	2.2220E-03
R-098	2.2220E-03
R-099	2.2220E-03
R-100	2.2220E-03
R-101	2.2220E-03
R-102	2.2220E-03
R-103	2.2220E-03
R-104	2.2220E-03
R-105	2.2220E-03
R-106	2.2220E-03
R-107	2.2220E-03
R-108	2.2220E-03
R-109	2.2220E-03
R-110	2.2220E-03
R-111	2.2220E-03
R-112	2.2220E-03
R-113	2.2220E-03
R-114	2.2220E-03
R-115	2.2220E-03
R-116	2.2220E-03
R-117	2.2220E-03
R-118	2.2220E-03
R-119	2.2220E-03
R-120	2.2220E-03
R-121	2.2220E-03
R-122	2.2220E-03
R-123	2.2220E-03
R-124	2.2220E-03
R-125	2.2220E-03
R-126	2.2220E-03
R-127	2.2220E-03
R-128	2.2220E-03
R-129	2.2220E-03
R-130	2.2220E-03
R-131	2.2220E-03
R-132	2.2220E-03
R-133	2.2220E-03
R-134	2.2220E-03
R-135	2.2220E-03
R-136	2.2220E-03
R-137	2.2220E-03
R-138	2.2220E-03
R-139	2.2220E-03
R-140	2.2220E-03
R-141	2.2220E-03
R-142	2.2220E-03
R-143	2.2220E-03
R-144	2.2220E-03
R-145	2.2220E-03
R-146	2.2220E-03
R-147	2.2220E-03
R-148	2.2220E-03
R-149	2.2220E-03
R-150	2.2220E-03
R-151	2.2220E-03

```
R-152  2.2220E-03
R-153  2.2220E-03
R-154  2.2220E-03
R-155  2.2220E-03
R-156  2.2220E-03
R-157  2.2220E-03
R-158  2.2220E-03
R-159  2.2220E-03
R-160  2.2220E-03
R-161  2.2220E-03
R-162  2.2220E-03
R-163  2.2220E-03
R-164  2.2220E-03
R-165  2.2220E-03
R-166  2.2220E-03
R-167  2.2220E-03
R-168  2.2220E-03
R-169  2.2220E-03
R-170  2.2220E-03
R-171  2.2220E-03
R-172  2.2220E-03
R-173  2.2220E-03
R-174  2.2220E-03
R-175  2.2220E-03
R-176  2.2220E-03
R-177  2.2220E-03
R-178  2.2220E-03
R-179  2.2220E-03
R-180  2.2220E-03
R-181  2.2220E-03
R-182  2.2220E-03
R-183  2.2220E-03
R-184  2.2220E-03
R-185  2.2220E-03
R-186  2.2220E-03
R-187  2.2220E-03
R-188  2.2220E-03
R-189  2.2220E-03
R-190  2.2220E-03
R-191  2.2220E-03
R-192  2.2220E-03
R-193  2.2220E-03
         0 3.100E+02                                      */TOP            layer: 5
         0 1.111E-01                                      */HY             layer: 6
         0 3.000E+02                                      */BOT            layer: 6
         0 1.481E-03                                      */VCONT          layer: 6
         0 3.050E+02                                      */TOP            layer: 6
         0 1.111E+00                                      */T              layer: 7
         0 1.111E-03                                      */VCONT          layer: 7
         0 1.111E+00                                      */T              layer: 8
```

Table F-4 Input file for the Drain Package in the Steady State and Baldhill Dam Simulations

```
    1000         2           drains not below:      317.69
      27         1
       4         2         1     317.69      1307
       4         3         1     317.69      1307
       4         4         1     317.69      1307
       4         5         1     317.69      1307
       4         6         1     317.69      1307
       4         7         1     317.69      1307
       4         8         1     317.69      1307
       4         9         1     317.69      1307
       4        11         1     317.69      1307
       3        12         1      319.2      1307
       3        13         1        322      1307
       2        14         1      323.8      1307
       2        15         1      325.6      1307
       1        16         1      326.1      1307
       1        17         1      326.5      1307
       1        18         1      326.7      1307
       1        19         1      326.9      1307
       1        20         1      327.2      1307
       1        21         1      327.6      1307
       1        22         1        328      1307
       1        23         1      328.1      1307
       1        24         1      328.4      1307
       1        25         1      329.1      1307
       1        26         1      329.6      1307
       1        26         1      329.8      1307
       1        27         1        330      1307
       1        28         1      330.1      1307
      -1          StressPeriod:   2
      -1          StressPeriod:   3
      -1          StressPeriod:   4
      -1          StressPeriod:   5
      -1          StressPeriod:   6
      -1          StressPeriod:   7
      -1          StressPeriod:   8
      -1          StressPeriod:   9
      -1          StressPeriod:  10
      -1          StressPeriod:  11
      -1          StressPeriod:  12
      -1          StressPeriod:  13
      -1          StressPeriod:  14
      -1          StressPeriod:  15
      -1          StressPeriod:  16
      -1          StressPeriod:  17
      -1          StressPeriod:  18
      -1          StressPeriod:  19
      -1          StressPeriod:  20
      -1          StressPeriod:  21
      -1          StressPeriod:  22
      -1          StressPeriod:  23
      -1          StressPeriod:  24
      -1          StressPeriod:  25
      -1          StressPeriod:  26
      -1          StressPeriod:  27
      -1          StressPeriod:  28
      -1          StressPeriod:  29
      -1          StressPeriod:  30
      -1          StressPeriod:  31
      -1          StressPeriod:  32
      -1          StressPeriod:  33
      -1          StressPeriod:  34
```

```
          -1         StressPeriod:  35
          -1         StressPeriod:  36
          -1         StressPeriod:  37
          -1         StressPeriod:  38
          -1         StressPeriod:  39
          -1         StressPeriod:  40
          -1         StressPeriod:  41
          -1         StressPeriod:  42
          -1         StressPeriod:  43
          -1         StressPeriod:  44
          -1         StressPeriod:  45
          -1         StressPeriod:  46
          -1         StressPeriod:  47
          -1         StressPeriod:  48
          -1         StressPeriod:  49
          -1         StressPeriod:  50
          -1         StressPeriod:  51
          -1         StressPeriod:  52
          -1         StressPeriod:  53
          -1         StressPeriod:  54
          -1         StressPeriod:  55
          -1         StressPeriod:  56
          -1         StressPeriod:  57
          -1         StressPeriod:  58
          -1         StressPeriod:  59
          -1         StressPeriod:  60
          -1         StressPeriod:  61
          -1         StressPeriod:  62
          -1         StressPeriod:  63
          -1         StressPeriod:  64
          -1         StressPeriod:  65
          -1         StressPeriod:  66
          -1         StressPeriod:  67
          -1         StressPeriod:  68
          -1         StressPeriod:  69
          -1         StressPeriod:  70
6
```

Table F-5 Input file for the Evapotranspiration Package in the Steady State Simulation

```
         2         2
         0         0         0         0     StressPeriod:   1
        15 0.000E+00(6x,10f11.0)                -12   */SURF
R-001  3.1299E+02
R-002  3.1299E+02
R-003  3.1299E+02
R-004  3.1299E+02
R-005  3.1299E+02
R-006  3.1299E+02
R-007  3.1299E+02
R-008  3.1299E+02
R-009  3.1152E+02
R-010  3.1432E+02
R-011  3.1702E+02
R-012  3.1982E+02
R-013  3.2162E+02
R-014  3.2342E+02
R-015  3.2392E+02
R-016  3.2432E+02
R-017  3.2452E+02
R-018  3.2472E+02
R-019  3.2502E+02
R-020  3.2542E+02
R-021  3.2582E+02
R-022  3.2592E+02
R-023  3.2622E+02
R-024  3.2692E+02
R-025  3.2742E+02
R-026  3.2762E+02
R-027  3.2782E+02
R-028  3.2792E+02
R-029  3.2792E+02
R-030  3.2792E+02
R-031  3.2792E+02
R-032  3.2782E+02
R-033  3.2782E+02
R-034  3.2752E+02
R-035  3.2702E+02
R-036  3.2682E+02
R-037  3.2682E+02
R-038  3.2682E+02
R-039  3.2682E+02
R-040  3.2682E+02
R-041  3.2682E+02
R-042  3.2682E+02
R-043  3.2682E+02
R-044  3.2692E+02
R-045  3.2722E+02
R-046  3.2742E+02
R-047  3.2742E+02
R-048  3.2732E+02
R-049  3.2682E+02
R-050  3.2642E+02
R-051  3.2692E+02
R-052  3.2742E+02
R-053  3.2742E+02
R-054  3.2772E+02
R-055  3.2782E+02
R-056  3.2782E+02
R-057  3.2782E+02
R-058  3.2782E+02
R-059  3.2782E+02
R-060  3.2782E+02
```

R-061	3.2782E+02
R-062	3.2782E+02
R-063	3.2762E+02
R-064	3.2732E+02
R-065	3.2712E+02
R-066	3.2682E+02
R-067	3.2672E+02
R-068	3.2652E+02
R-069	3.2642E+02
R-070	3.2622E+02
R-071	3.2622E+02
R-072	3.2642E+02
R-073	3.2682E+02
R-074	3.2682E+02
R-075	3.2682E+02
R-076	3.2682E+02
R-077	3.2682E+02
R-078	3.2702E+02
R-079	3.2752E+02
R-080	3.2772E+02
R-081	3.2732E+02
R-082	3.2682E+02
R-083	3.2692E+02
R-084	3.2712E+02
R-085	3.2732E+02
R-086	3.2752E+02
R-087	3.2772E+02
R-088	3.2812E+02
R-089	3.2852E+02
R-090	3.2882E+02
R-091	3.2912E+02
R-092	3.2952E+02
R-093	3.2982E+02
R-094	3.2982E+02
R-095	3.2982E+02
R-096	3.2982E+02
R-097	3.2982E+02
R-098	3.2972E+02
R-099	3.2932E+02
R-100	3.2902E+02
R-101	3.2922E+02
R-102	3.2932E+02
R-103	3.2912E+02
R-104	3.2892E+02
R-105	3.2882E+02
R-106	3.2882E+02
R-107	3.2862E+02
R-108	3.2822E+02
R-109	3.2782E+02
R-110	3.2772E+02
R-111	3.2792E+02
R-112	3.2802E+02
R-113	3.2822E+02
R-114	3.2842E+02
R-115	3.2852E+02
R-116	3.2872E+02
R-117	3.2882E+02
R-118	3.2862E+02
R-119	3.2822E+02
R-120	3.2782E+02
R-121	3.2782E+02
R-122	3.2782E+02
R-123	3.2782E+02
R-124	3.2782E+02
R-125	3.2782E+02
R-126	3.2782E+02

R-127	3.2782E+02
R-128	3.2782E+02
R-129	3.2782E+02
R-130	3.2782E+02
R-131	3.2782E+02
R-132	3.2782E+02
R-133	3.2782E+02
R-134	3.2782E+02
R-135	3.2782E+02
R-136	3.2752E+02
R-137	3.2732E+02
R-138	3.2742E+02
R-139	3.2762E+02
R-140	3.2772E+02
R-141	3.2782E+02
R-142	3.2782E+02
R-143	3.2782E+02
R-144	3.2782E+02
R-145	3.2782E+02
R-146	3.2782E+02
R-147	3.2792E+02
R-148	3.2812E+02
R-149	3.2842E+02
R-150	3.2872E+02
R-151	3.2892E+02
R-152	3.2942E+02
R-153	3.2982E+02
R-154	3.2982E+02
R-155	3.2982E+02
R-156	3.2982E+02
R-157	3.2982E+02
R-158	3.2982E+02
R-159	3.2982E+02
R-160	3.2982E+02
R-161	3.2982E+02
R-162	3.2982E+02
R-163	3.2982E+02
R-164	3.2982E+02
R-165	3.2982E+02
R-166	3.2982E+02
R-167	3.2982E+02
R-168	3.2982E+02
R-169	3.2982E+02
R-170	3.2982E+02
R-171	3.2982E+02
R-172	3.3002E+02
R-173	3.3032E+02
R-174	3.3042E+02
R-175	3.3062E+02
R-176	3.3082E+02
R-177	3.3082E+02
R-178	3.3082E+02
R-179	3.3082E+02
R-180	3.3082E+02
R-181	3.3082E+02
R-182	3.3082E+02
R-183	3.3082E+02
R-184	3.3082E+02
R-185	3.3082E+02
R-186	3.3092E+02
R-187	3.3132E+02
R-188	3.3182E+02
R-189	3.3182E+02
R-190	3.3182E+02
R-191	3.3182E+02
R-192	3.3182E+02

```
R-193   3.3182E+02
          0 2.087E-03                                                  */EVTR
          0 1.248E+00                                                  */EXDP
         15          0(6x,20i3)                                  -2    */IEVT
R-001    4
R-002    4
R-003    4
R-004    4
R-005    4
R-006    4
R-007    4
R-008    4
R-009    4
R-010    4
R-011    3
R-012    3
R-013    2
R-014    2
R-015    2
R-016    2
R-017    2
R-018    2
R-019    1
R-020    1
R-021    1
R-022    1
R-023    1
R-024    1
R-025    1
R-026    1
R-027    1
R-028    1
R-029    1
R-030    1
R-031    1
R-032    1
R-033    1
R-034    1
R-035    1
R-036    1
R-037    1
R-038    1
R-039    1
R-040    1
R-041    1
R-042    1
R-043    1
R-044    1
R-045    1
R-046    1
R-047    1
R-048    1
R-049    1
R-050    1
R-051    1
R-052    1
R-053    1
R-054    1
R-055    1
R-056    1
R-057    1
R-058    1
R-059    1
R-060    1
R-061    1
R-062    1
```

R-063	1
R-064	1
R-065	1
R-066	1
R-067	1
R-068	1
R-069	1
R-070	1
R-071	1
R-072	1
R-073	1
R-074	1
R-075	1
R-076	1
R-077	1
R-078	1
R-079	1
R-080	1
R-081	1
R-082	1
R-083	1
R-084	1
R-085	1
R-086	1
R-087	1
R-088	1
R-089	1
R-090	1
R-091	1
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R-102	1
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R-107	1
R-108	1
R-109	1
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R-111	1
R-112	1
R-113	1
R-114	1
R-115	1
R-116	1
R-117	1
R-118	1
R-119	1
R-120	1
R-121	1
R-122	1
R-123	1
R-124	1
R-125	1
R-126	1
R-127	1
R-128	1

R-129	1
R-130	1
R-131	1
R-132	1
R-133	1
R-134	1
R-135	1
R-136	1
R-137	1
R-138	1
R-139	1
R-140	1
R-141	1
R-142	1
R-143	1
R-144	1
R-145	1
R-146	1
R-147	1
R-148	1
R-149	1
R-150	1
R-151	1
R-152	1
R-153	1
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R-159	1
R-160	1
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R-163	1
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R-165	1
R-166	1
R-167	1
R-168	1
R-169	1
R-170	1
R-171	1
R-172	1
R-173	1
R-174	1
R-175	1
R-176	1
R-177	1
R-178	1
R-179	1
R-180	1
R-181	1
R-182	1
R-183	1
R-184	1
R-185	1
R-186	1
R-187	1
R-188	1
R-189	1
R-190	1
R-191	1
R-192	1
R-193	1
6	

Table F-6   Input file for the Recharge Package in the Steady State Simulation

```
         2         2
         0         0     StressPeriod:   1
         0 1.390E-03                                   */RECH
        18         0(6x,20i3)                    -2    */irch
R-001   4
R-002   4
R-003   4
R-004   4
R-005   4
R-006   4
R-007   4
R-008   4
R-009   4
R-010   4
R-011   3
R-012   3
R-013   2
R-014   2
R-015   2
R-016   2
R-017   2
R-018   2
R-019   1
R-020   1
R-021   1
R-022   1
R-023   1
R-024   1
R-025   1
R-026   1
R-027   1
R-028   1
R-029   1
R-030   1
R-031   1
R-032   1
R-033   1
R-034   1
R-035   1
R-036   1
R-037   1
R-038   1
R-039   1
R-040   1
R-041   1
R-042   1
R-043   1
R-044   1
R-045   1
R-046   1
R-047   1
R-048   1
R-049   1
R-050   1
R-051   1
R-052   1
R-053   1
R-054   1
R-055   1
R-056   1
R-057   1
R-058   1
R-059   1
```

R-060	1
R-061	1
R-062	1
R-063	1
R-064	1
R-065	1
R-066	1
R-067	1
R-068	1
R-069	1
R-070	1
R-071	1
R-072	1
R-073	1
R-074	1
R-075	1
R-076	1
R-077	1
R-078	1
R-079	1
R-080	1
R-081	1
R-082	1
R-083	1
R-084	1
R-085	1
R-086	1
R-087	1
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R-093	1
R-094	1
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R-116	1
R-117	1
R-118	1
R-119	1
R-120	1
R-121	1
R-122	1
R-123	1
R-124	1
R-125	1

R-126	1
R-127	1
R-128	1
R-129	1
R-130	1
R-131	1
R-132	1
R-133	1
R-134	1
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R-137	1
R-138	1
R-139	1
R-140	1
R-141	1
R-142	1
R-143	1
R-144	1
R-145	1
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R-153	1
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R-169	1
R-170	1
R-171	1
R-172	1
R-173	1
R-174	1
R-175	1
R-176	1
R-177	1
R-178	1
R-179	1
R-180	1
R-181	1
R-182	1
R-183	1
R-184	1
R-185	1
R-186	1
R-187	1
R-188	1
R-189	1
R-190	1
R-191	1

R-192	1
R-193	1

Table F-7A Input File for the Time-variant Specified Head (CHD) Package in the Steady State Simulation

```
      1000
         1     StressPeriod:   1
         4         1        1 3.131E+02 3.131E+02
```

Table F-7B Input File for the Preconditioned Conjugate-gradient Package(PCG2) Package in the Steady State Simulation

```
                   Input file for the in the Steady State Simulation

       350        10         1
 0.100E-04 0.100E+00    0.9700         2         0         0         0
```

**Table F-8	Input file for the Evapotranspiration Package for the Devils Lake Outlet Simulation**

```
         2         2
         0         0         0         0     StressPeriod:   1
        15 0.000E+00(6x,10f11.0)               -12   */SURF
R-001  3.1299E+02
R-002  3.1299E+02
R-003  3.1299E+02
R-004  3.1299E+02
R-005  3.1299E+02
R-006  3.1299E+02
R-007  3.1299E+02
R-008  3.1299E+02
R-009  3.1152E+02
R-010  3.1432E+02
R-011  3.1702E+02
R-012  3.1982E+02
R-013  3.2162E+02
R-014  3.2342E+02
R-015  3.2392E+02
R-016  3.2432E+02
R-017  3.2452E+02
R-018  3.2472E+02
R-019  3.2502E+02
R-020  3.2542E+02
R-021  3.2582E+02
R-022  3.2592E+02
R-023  3.2622E+02
R-024  3.2692E+02
R-025  3.2742E+02
R-026  3.2762E+02
R-027  3.2782E+02
R-028  3.2792E+02
R-029  3.2792E+02
R-030  3.2792E+02
R-031  3.2792E+02
R-032  3.2782E+02
R-033  3.2782E+02
R-034  3.2752E+02
R-035  3.2702E+02
R-036  3.2682E+02
R-037  3.2682E+02
R-038  3.2682E+02
R-039  3.2682E+02
R-040  3.2682E+02
R-041  3.2682E+02
R-042  3.2682E+02
R-043  3.2682E+02
R-044  3.2692E+02
R-045  3.2722E+02
R-046  3.2742E+02
R-047  3.2742E+02
R-048  3.2732E+02
R-049  3.2682E+02
R-050  3.2642E+02
R-051  3.2692E+02
R-052  3.2742E+02
R-053  3.2742E+02
R-054  3.2772E+02
R-055  3.2782E+02
R-056  3.2782E+02
R-057  3.2782E+02
R-058  3.2782E+02
R-059  3.2782E+02
R-060  3.2782E+02
```

R-061	3.2782E+02
R-062	3.2782E+02
R-063	3.2762E+02
R-064	3.2732E+02
R-065	3.2712E+02
R-066	3.2682E+02
R-067	3.2672E+02
R-068	3.2652E+02
R-069	3.2642E+02
R-070	3.2622E+02
R-071	3.2622E+02
R-072	3.2642E+02
R-073	3.2682E+02
R-074	3.2682E+02
R-075	3.2682E+02
R-076	3.2682E+02
R-077	3.2682E+02
R-078	3.2702E+02
R-079	3.2752E+02
R-080	3.2772E+02
R-081	3.2732E+02
R-082	3.2682E+02
R-083	3.2692E+02
R-084	3.2712E+02
R-085	3.2732E+02
R-086	3.2752E+02
R-087	3.2772E+02
R-088	3.2812E+02
R-089	3.2852E+02
R-090	3.2882E+02
R-091	3.2912E+02
R-092	3.2952E+02
R-093	3.2982E+02
R-094	3.2982E+02
R-095	3.2982E+02
R-096	3.2982E+02
R-097	3.2982E+02
R-098	3.2972E+02
R-099	3.2932E+02
R-100	3.2902E+02
R-101	3.2922E+02
R-102	3.2932E+02
R-103	3.2912E+02
R-104	3.2892E+02
R-105	3.2882E+02
R-106	3.2882E+02
R-107	3.2862E+02
R-108	3.2822E+02
R-109	3.2782E+02
R-110	3.2772E+02
R-111	3.2792E+02
R-112	3.2802E+02
R-113	3.2822E+02
R-114	3.2842E+02
R-115	3.2852E+02
R-116	3.2872E+02
R-117	3.2882E+02
R-118	3.2862E+02
R-119	3.2822E+02
R-120	3.2782E+02
R-121	3.2782E+02
R-122	3.2782E+02
R-123	3.2782E+02
R-124	3.2782E+02
R-125	3.2782E+02
R-126	3.2782E+02

R-127	3.2782E+02
R-128	3.2782E+02
R-129	3.2782E+02
R-130	3.2782E+02
R-131	3.2782E+02
R-132	3.2782E+02
R-133	3.2782E+02
R-134	3.2782E+02
R-135	3.2782E+02
R-136	3.2752E+02
R-137	3.2732E+02
R-138	3.2742E+02
R-139	3.2762E+02
R-140	3.2772E+02
R-141	3.2782E+02
R-142	3.2782E+02
R-143	3.2782E+02
R-144	3.2782E+02
R-145	3.2782E+02
R-146	3.2782E+02
R-147	3.2792E+02
R-148	3.2812E+02
R-149	3.2842E+02
R-150	3.2872E+02
R-151	3.2892E+02
R-152	3.2942E+02
R-153	3.2982E+02
R-154	3.2982E+02
R-155	3.2982E+02
R-156	3.2982E+02
R-157	3.2982E+02
R-158	3.2982E+02
R-159	3.2982E+02
R-160	3.2982E+02
R-161	3.2982E+02
R-162	3.2982E+02
R-163	3.2982E+02
R-164	3.2982E+02
R-165	3.2982E+02
R-166	3.2982E+02
R-167	3.2982E+02
R-168	3.2982E+02
R-169	3.2982E+02
R-170	3.2982E+02
R-171	3.2982E+02
R-172	3.3002E+02
R-173	3.3032E+02
R-174	3.3042E+02
R-175	3.3062E+02
R-176	3.3082E+02
R-177	3.3082E+02
R-178	3.3082E+02
R-179	3.3082E+02
R-180	3.3082E+02
R-181	3.3082E+02
R-182	3.3082E+02
R-183	3.3082E+02
R-184	3.3082E+02
R-185	3.3082E+02
R-186	3.3092E+02
R-187	3.3132E+02
R-188	3.3182E+02
R-189	3.3182E+02
R-190	3.3182E+02
R-191	3.3182E+02
R-192	3.3182E+02

```
R-193   3.3182E+02
          0 0.000E+00                                        */EVTR
          0 1.248E+00                                        */EXDP
         15         0(6x,20i3)                      -2    */IEVT
R-001    4
R-002    4
R-003    4
R-004    4
R-005    4
R-006    4
R-007    4
R-008    4
R-009    4
R-010    4
R-011    3
R-012    3
R-013    2
R-014    2
R-015    2
R-016    2
R-017    2
R-018    2
R-019    1
R-020    1
R-021    1
R-022    1
R-023    1
R-024    1
R-025    1
R-026    1
R-027    1
R-028    1
R-029    1
R-030    1
R-031    1
R-032    1
R-033    1
R-034    1
R-035    1
R-036    1
R-037    1
R-038    1
R-039    1
R-040    1
R-041    1
R-042    1
R-043    1
R-044    1
R-045    1
R-046    1
R-047    1
R-048    1
R-049    1
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R-051    1
R-052    1
R-053    1
R-054    1
R-055    1
R-056    1
R-057    1
R-058    1
R-059    1
R-060    1
R-061    1
R-062    1
```

R-063	1
R-064	1
R-065	1
R-066	1
R-067	1
R-068	1
R-069	1
R-070	1
R-071	1
R-072	1
R-073	1
R-074	1
R-075	1
R-076	1
R-077	1
R-078	1
R-079	1
R-080	1
R-081	1
R-082	1
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R-085	1
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R-087	1
R-088	1
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R-106	1
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R-109	1
R-110	1
R-111	1
R-112	1
R-113	1
R-114	1
R-115	1
R-116	1
R-117	1
R-118	1
R-119	1
R-120	1
R-121	1
R-122	1
R-123	1
R-124	1
R-125	1
R-126	1
R-127	1
R-128	1

```
R-129   1
R-130   1
R-131   1
R-132   1
R-133   1
R-134   1
R-135   1
R-136   1
R-137   1
R-138   1
R-139   1
R-140   1
R-141   1
R-142   1
R-143   1
R-144   1
R-145   1
R-146   1
R-147   1
R-148   1
R-149   1
R-150   1
R-151   1
R-152   1
R-153   1
R-154   1
R-155   1
R-156   1
R-157   1
R-158   1
R-159   1
R-160   1
R-161   1
R-162   1
R-163   1
R-164   1
R-165   1
R-166   1
R-167   1
R-168   1
R-169   1
R-170   1
R-171   1
R-172   1
R-173   1
R-174   1
R-175   1
R-176   1
R-177   1
R-178   1
R-179   1
R-180   1
R-181   1
R-182   1
R-183   1
R-184   1
R-185   1
R-186   1
R-187   1
R-188   1
R-189   1
R-190   1
R-191   1
R-192   1
R-193   1
        -1         -1         -1         -1     StressPeriod:    2
```

```
-1        -1        -1        -1     StressPeriod:   3
-1         0        -1        -1     StressPeriod:   4
 0 2.087E-03                                 */EVTR
-1        -1        -1        -1     StressPeriod:   5
-1        -1        -1        -1     StressPeriod:   6
-1        -1        -1        -1     StressPeriod:   7
-1        -1        -1        -1     StressPeriod:   8
-1        -1        -1        -1     StressPeriod:   9
-1        -1        -1        -1     StressPeriod:  10
-1         0        -1        -1     StressPeriod:  11
 0 0.000E+00                                 */EVTR
-1        -1        -1        -1     StressPeriod:  12
```

Table F-9 Input file for the Recharge Package for the Devils Lake Outlet Simulation

```
         3         2
         0         0         1
         0 0.0000000 January
         0         0         1
         0 0.0000000 February
         0         0         1
         0 0.0021867 March
         0         0         1
         0 0.0015667 April
         0         0         1
         0 0.0020079 May
         0         0         1
         0 0.0030488 June
         0         0         1
         0 0.0022948 July
         0         0         1
         0 0.0023358 August
         0         0         1
         0 0.0013127 September
         0         0         1
         0 0.0009425 October
         0         0         1
         0 0.0006352 November
         0         0         1
         0 0.0000000 December
```

Table F-10 Input file for the Time-variant Specified Head (CHD) Package for the Devils Lake Outlet Simulation: Baseline Condition

```
      1000 CHD input file for baseline conditions at river mile                  131.7
         1     StressPeriod:   1 (January)
         4         1         1   312.035   312.066
         1     StressPeriod:   2 (February)
         4         1         1   312.066   312.465
         1     StressPeriod:   2 (March)
         4         1         1   312.465   313.190
         1     StressPeriod:   2 (April)
         4         1         1   313.190   312.604
         1     StressPeriod:   2 (May)
         4         1         1   312.604   312.277
         1     StressPeriod:   2 (June)
         4         1         1   312.277   312.253
         1     StressPeriod:   2 (July)
         4         1         1   312.253   312.123
         1     StressPeriod:   2 (August)
         4         1         1   312.123   312.039
         1     StressPeriod:   2 (September)
         4         1         1   312.039   312.038
         1     StressPeriod:   2 (October)
         4         1         1   312.038   312.059
         1     StressPeriod:   2 (November)
         4         1         1   312.059   312.045
         1     StressPeriod:   2 (December)
         4         1         1   312.045   312.035
6
```

Table F-11 Input file for the Time-variant Specified Head (CHD) Package for the Devils Lake Outlet Simulation: With the Devils Lake Outlet

```
      1000 CHD input file for operation of devil's lake outlet, river mile       131.7
         1     StressPeriod:   1 (January)
         4         1         1   312.035   312.066
         1     StressPeriod:   2 (February)
         4         1         1   312.066   312.465
         1     StressPeriod:   2 (March)
         4         1         1   312.465   313.190
         1     StressPeriod:   2 (April)
         4         1         1   313.190   313.063
         1     StressPeriod:   2 (May)
         4         1         1   313.063   312.754
         1     StressPeriod:   2 (June)
         4         1         1   312.754   312.728
         1     StressPeriod:   2 (July)
         4         1         1   312.728   312.615
         1     StressPeriod:   2 (August)
         4         1         1   312.615   312.541
         1     StressPeriod:   2 (September)
         4         1         1   312.541   312.539
         1     StressPeriod:   2 (October)
         4         1         1   312.539   312.557
         1     StressPeriod:   2 (November)
         4         1         1   312.557   312.045
         1     StressPeriod:   2 (December)
         4         1         1   312.045   312.035
6
```

Table F-12   Input file for the Evapotranspiration Package for the Baldhill Dam Pool Raise Simulation

```
         2         2
         0         0         0         0     StressPeriod:   1
        15 0.000E+00(6x,10f11.0)              -12   */SURF
R-001  3.1299E+02
R-002  3.1299E+02
R-003  3.1299E+02
R-004  3.1299E+02
R-005  3.1299E+02
R-006  3.1299E+02
R-007  3.1299E+02
R-008  3.1299E+02
R-009  3.1152E+02
R-010  3.1432E+02
R-011  3.1702E+02
R-012  3.1982E+02
R-013  3.2162E+02
R-014  3.2342E+02
R-015  3.2392E+02
R-016  3.2432E+02
R-017  3.2452E+02
R-018  3.2472E+02
R-019  3.2502E+02
R-020  3.2542E+02
R-021  3.2582E+02
R-022  3.2592E+02
R-023  3.2622E+02
R-024  3.2692E+02
R-025  3.2742E+02
R-026  3.2762E+02
R-027  3.2782E+02
R-028  3.2792E+02
R-029  3.2792E+02
R-030  3.2792E+02
R-031  3.2792E+02
R-032  3.2782E+02
R-033  3.2782E+02
R-034  3.2752E+02
R-035  3.2702E+02
R-036  3.2682E+02
R-037  3.2682E+02
R-038  3.2682E+02
R-039  3.2682E+02
R-040  3.2682E+02
R-041  3.2682E+02
R-042  3.2682E+02
R-043  3.2682E+02
R-044  3.2692E+02
R-045  3.2722E+02
R-046  3.2742E+02
R-047  3.2742E+02
R-048  3.2732E+02
R-049  3.2682E+02
R-050  3.2642E+02
R-051  3.2692E+02
R-052  3.2742E+02
R-053  3.2742E+02
R-054  3.2772E+02
R-055  3.2782E+02
R-056  3.2782E+02
R-057  3.2782E+02
R-058  3.2782E+02
R-059  3.2782E+02
R-060  3.2782E+02
```

R-061	3.2782E+02
R-062	3.2782E+02
R-063	3.2762E+02
R-064	3.2732E+02
R-065	3.2712E+02
R-066	3.2682E+02
R-067	3.2672E+02
R-068	3.2652E+02
R-069	3.2642E+02
R-070	3.2622E+02
R-071	3.2622E+02
R-072	3.2642E+02
R-073	3.2682E+02
R-074	3.2682E+02
R-075	3.2682E+02
R-076	3.2682E+02
R-077	3.2682E+02
R-078	3.2702E+02
R-079	3.2752E+02
R-080	3.2772E+02
R-081	3.2732E+02
R-082	3.2682E+02
R-083	3.2692E+02
R-084	3.2712E+02
R-085	3.2732E+02
R-086	3.2752E+02
R-087	3.2772E+02
R-088	3.2812E+02
R-089	3.2852E+02
R-090	3.2882E+02
R-091	3.2912E+02
R-092	3.2952E+02
R-093	3.2982E+02
R-094	3.2982E+02
R-095	3.2982E+02
R-096	3.2982E+02
R-097	3.2982E+02
R-098	3.2972E+02
R-099	3.2932E+02
R-100	3.2902E+02
R-101	3.2922E+02
R-102	3.2932E+02
R-103	3.2912E+02
R-104	3.2892E+02
R-105	3.2882E+02
R-106	3.2882E+02
R-107	3.2862E+02
R-108	3.2822E+02
R-109	3.2782E+02
R-110	3.2772E+02
R-111	3.2792E+02
R-112	3.2802E+02
R-113	3.2822E+02
R-114	3.2842E+02
R-115	3.2852E+02
R-116	3.2872E+02
R-117	3.2882E+02
R-118	3.2862E+02
R-119	3.2822E+02
R-120	3.2782E+02
R-121	3.2782E+02
R-122	3.2782E+02
R-123	3.2782E+02
R-124	3.2782E+02
R-125	3.2782E+02
R-126	3.2782E+02

R-127	3.2782E+02
R-128	3.2782E+02
R-129	3.2782E+02
R-130	3.2782E+02
R-131	3.2782E+02
R-132	3.2782E+02
R-133	3.2782E+02
R-134	3.2782E+02
R-135	3.2782E+02
R-136	3.2752E+02
R-137	3.2732E+02
R-138	3.2742E+02
R-139	3.2762E+02
R-140	3.2772E+02
R-141	3.2782E+02
R-142	3.2782E+02
R-143	3.2782E+02
R-144	3.2782E+02
R-145	3.2782E+02
R-146	3.2782E+02
R-147	3.2792E+02
R-148	3.2812E+02
R-149	3.2842E+02
R-150	3.2872E+02
R-151	3.2892E+02
R-152	3.2942E+02
R-153	3.2982E+02
R-154	3.2982E+02
R-155	3.2982E+02
R-156	3.2982E+02
R-157	3.2982E+02
R-158	3.2982E+02
R-159	3.2982E+02
R-160	3.2982E+02
R-161	3.2982E+02
R-162	3.2982E+02
R-163	3.2982E+02
R-164	3.2982E+02
R-165	3.2982E+02
R-166	3.2982E+02
R-167	3.2982E+02
R-168	3.2982E+02
R-169	3.2982E+02
R-170	3.2982E+02
R-171	3.2982E+02
R-172	3.3002E+02
R-173	3.3032E+02
R-174	3.3042E+02
R-175	3.3062E+02
R-176	3.3082E+02
R-177	3.3082E+02
R-178	3.3082E+02
R-179	3.3082E+02
R-180	3.3082E+02
R-181	3.3082E+02
R-182	3.3082E+02
R-183	3.3082E+02
R-184	3.3082E+02
R-185	3.3082E+02
R-186	3.3092E+02
R-187	3.3132E+02
R-188	3.3182E+02
R-189	3.3182E+02
R-190	3.3182E+02
R-191	3.3182E+02
R-192	3.3182E+02

```
R-193  3.3182E+02
         0 2.087E-03                                         */EVTR
         0 1.248E+00                                         */EXDP
        15          0(6x,20i3)                         -2    */IEVT
R-001   4
R-002   4
R-003   4
R-004   4
R-005   4
R-006   4
R-007   4
R-008   4
R-009   4
R-010   4
R-011   3
R-012   3
R-013   2
R-014   2
R-015   2
R-016   2
R-017   2
R-018   2
R-019   1
R-020   1
R-021   1
R-022   1
R-023   1
R-024   1
R-025   1
R-026   1
R-027   1
R-028   1
R-029   1
R-030   1
R-031   1
R-032   1
R-033   1
R-034   1
R-035   1
R-036   1
R-037   1
R-038   1
R-039   1
R-040   1
R-041   1
R-042   1
R-043   1
R-044   1
R-045   1
R-046   1
R-047   1
R-048   1
R-049   1
R-050   1
R-051   1
R-052   1
R-053   1
R-054   1
R-055   1
R-056   1
R-057   1
R-058   1
R-059   1
R-060   1
R-061   1
R-062   1
```

R-063	1
R-064	1
R-065	1
R-066	1
R-067	1
R-068	1
R-069	1
R-070	1
R-071	1
R-072	1
R-073	1
R-074	1
R-075	1
R-076	1
R-077	1
R-078	1
R-079	1
R-080	1
R-081	1
R-082	1
R-083	1
R-084	1
R-085	1
R-086	1
R-087	1
R-088	1
R-089	1
R-090	1
R-091	1
R-092	1
R-093	1
R-094	1
R-095	1
R-096	1
R-097	1
R-098	1
R-099	1
R-100	1
R-101	1
R-102	1
R-103	1
R-104	1
R-105	1
R-106	1
R-107	1
R-108	1
R-109	1
R-110	1
R-111	1
R-112	1
R-113	1
R-114	1
R-115	1
R-116	1
R-117	1
R-118	1
R-119	1
R-120	1
R-121	1
R-122	1
R-123	1
R-124	1
R-125	1
R-126	1
R-127	1
R-128	1

```
R-129   1
R-130   1
R-131   1
R-132   1
R-133   1
R-134   1
R-135   1
R-136   1
R-137   1
R-138   1
R-139   1
R-140   1
R-141   1
R-142   1
R-143   1
R-144   1
R-145   1
R-146   1
R-147   1
R-148   1
R-149   1
R-150   1
R-151   1
R-152   1
R-153   1
R-154   1
R-155   1
R-156   1
R-157   1
R-158   1
R-159   1
R-160   1
R-161   1
R-162   1
R-163   1
R-164   1
R-165   1
R-166   1
R-167   1
R-168   1
R-169   1
R-170   1
R-171   1
R-172   1
R-173   1
R-174   1
R-175   1
R-176   1
R-177   1
R-178   1
R-179   1
R-180   1
R-181   1
R-182   1
R-183   1
R-184   1
R-185   1
R-186   1
R-187   1
R-188   1
R-189   1
R-190   1
R-191   1
R-192   1
R-193   1
        -1        -1        -1        -1     StressPeriod:    2
```

```
     -1         -1         -1         -1     StressPeriod:   3
     -1         -1         -1         -1     StressPeriod:   4
     -1         -1         -1         -1     StressPeriod:   5
     -1         -1         -1         -1     StressPeriod:   6
     -1         -1         -1         -1     StressPeriod:   7
     -1         -1         -1         -1     StressPeriod:   8
     -1         -1         -1         -1     StressPeriod:   9
     -1         -1         -1         -1     StressPeriod:  10
     -1         -1         -1         -1     StressPeriod:  11
     -1         -1         -1         -1     StressPeriod:  12
     -1         -1         -1         -1     StressPeriod:  13
     -1         -1         -1         -1     StressPeriod:  14
     -1         -1         -1         -1     StressPeriod:  15
     -1         -1         -1         -1     StressPeriod:  16
     -1         -1         -1         -1     StressPeriod:  17
     -1         -1         -1         -1     StressPeriod:  18
     -1         -1         -1         -1     StressPeriod:  19
     -1         -1         -1         -1     StressPeriod:  20
     -1         -1         -1         -1     StressPeriod:  21
     -1         -1         -1         -1     StressPeriod:  22
     -1         -1         -1         -1     StressPeriod:  23
     -1         -1         -1         -1     StressPeriod:  24
     -1         -1         -1         -1     StressPeriod:  25
     -1         -1         -1         -1     StressPeriod:  26
     -1         -1         -1         -1     StressPeriod:  27
     -1         -1         -1         -1     StressPeriod:  28
     -1         -1         -1         -1     StressPeriod:  29
     -1         -1         -1         -1     StressPeriod:  30
     -1         -1         -1         -1     StressPeriod:  31
     -1         -1         -1         -1     StressPeriod:  32
     -1         -1         -1         -1     StressPeriod:  33
     -1         -1         -1         -1     StressPeriod:  34
     -1         -1         -1         -1     StressPeriod:  35
     -1         -1         -1         -1     StressPeriod:  36
     -1         -1         -1         -1     StressPeriod:  37
     -1         -1         -1         -1     StressPeriod:  38
     -1         -1         -1         -1     StressPeriod:  39
     -1         -1         -1         -1     StressPeriod:  40
     -1         -1         -1         -1     StressPeriod:  41
     -1         -1         -1         -1     StressPeriod:  42
     -1         -1         -1         -1     StressPeriod:  43
     -1         -1         -1         -1     StressPeriod:  44
     -1         -1         -1         -1     StressPeriod:  45
     -1         -1         -1         -1     StressPeriod:  46
     -1         -1         -1         -1     StressPeriod:  47
     -1         -1         -1         -1     StressPeriod:  48
     -1         -1         -1         -1     StressPeriod:  49
     -1         -1         -1         -1     StressPeriod:  50
     -1         -1         -1         -1     StressPeriod:  51
     -1         -1         -1         -1     StressPeriod:  52
     -1         -1         -1         -1     StressPeriod:  53
     -1         -1         -1         -1     StressPeriod:  54
     -1         -1         -1         -1     StressPeriod:  55
     -1         -1         -1         -1     StressPeriod:  56
     -1         -1         -1         -1     StressPeriod:  57
     -1         -1         -1         -1     StressPeriod:  58
     -1         -1         -1         -1     StressPeriod:  59
     -1         -1         -1         -1     StressPeriod:  60
     -1         -1         -1         -1     StressPeriod:  61
     -1         -1         -1         -1     StressPeriod:  62
     -1         -1         -1         -1     StressPeriod:  63
     -1         -1         -1         -1     StressPeriod:  64
     -1         -1         -1         -1     StressPeriod:  65
     -1         -1         -1         -1     StressPeriod:  66
     -1         -1         -1         -1     StressPeriod:  67
     -1         -1         -1         -1     StressPeriod:  68
```

```
   -1         -1         -1         -1     StressPeriod:  69
   -1         -1         -1         -1     StressPeriod:  70
```

Table F-13 Input file for the Recharge Package for the Baldhill Dam Pool Raise Simulation

```
         3         2
         0         0     StressPeriod:   1
         0 1.390E-03                                         */RECH
        -1         0     StressPeriod:   2
        -1        -1     StressPeriod:   3
        -1        -1     StressPeriod:   4
        -1        -1     StressPeriod:   5
        -1        -1     StressPeriod:   6
        -1        -1     StressPeriod:   7
        -1        -1     StressPeriod:   8
        -1        -1     StressPeriod:   9
        -1        -1     StressPeriod:  10
        -1        -1     StressPeriod:  11
        -1        -1     StressPeriod:  12
        -1        -1     StressPeriod:  13
        -1        -1     StressPeriod:  14
        -1        -1     StressPeriod:  15
        -1        -1     StressPeriod:  16
        -1        -1     StressPeriod:  17
        -1        -1     StressPeriod:  18
        -1        -1     StressPeriod:  19
        -1        -1     StressPeriod:  20
        -1        -1     StressPeriod:  21
        -1        -1     StressPeriod:  22
        -1        -1     StressPeriod:  23
        -1        -1     StressPeriod:  24
        -1        -1     StressPeriod:  25
        -1        -1     StressPeriod:  26
        -1        -1     StressPeriod:  27
        -1        -1     StressPeriod:  28
        -1        -1     StressPeriod:  29
        -1        -1     StressPeriod:  30
        -1        -1     StressPeriod:  31
        -1        -1     StressPeriod:  32
        -1        -1     StressPeriod:  33
        -1        -1     StressPeriod:  34
        -1        -1     StressPeriod:  35
        -1        -1     StressPeriod:  36
        -1        -1     StressPeriod:  37
        -1        -1     StressPeriod:  38
        -1        -1     StressPeriod:  39
        -1        -1     StressPeriod:  40
        -1        -1     StressPeriod:  41
        -1        -1     StressPeriod:  42
        -1        -1     StressPeriod:  43
        -1        -1     StressPeriod:  44
        -1        -1     StressPeriod:  45
        -1        -1     StressPeriod:  46
        -1        -1     StressPeriod:  47
        -1        -1     StressPeriod:  48
        -1        -1     StressPeriod:  49
        -1        -1     StressPeriod:  50
        -1        -1     StressPeriod:  51
        -1        -1     StressPeriod:  52
        -1        -1     StressPeriod:  53
        -1        -1     StressPeriod:  54
        -1        -1     StressPeriod:  55
        -1        -1     StressPeriod:  56
        -1        -1     StressPeriod:  57
        -1        -1     StressPeriod:  58
        -1        -1     StressPeriod:  59
        -1        -1     StressPeriod:  60
        -1        -1     StressPeriod:  61
```

```
-1        -1     StressPeriod:  62
-1        -1     StressPeriod:  63
-1        -1     StressPeriod:  64
-1        -1     StressPeriod:  65
-1        -1     StressPeriod:  66
-1        -1     StressPeriod:  67
-1        -1     StressPeriod:  68
-1        -1     StressPeriod:  69
-1        -1     StressPeriod:  70
```

Table F-14 Input file for the Time-variant Specified Head (CHD) Package for the Baldhill Dam Pool Raise Simulation: Baseline Condition

```
1000 CHD input file for baseline conditions:
   1    StressPeriod:   1 (Day 1)
   4        1         1   313.108   313.108
   1    StressPeriod:   2 (Day 2)
   4        1         1   313.570   313.570
   1    StressPeriod:   3 (Day 3)
   4        1         1   313.730   313.730
   1    StressPeriod:   4 (Day 4)
   4        1         1   314.216   314.216
   1    StressPeriod:   5 (Day 5)
   4        1         1   314.912   314.912
   1    StressPeriod:   6 (Day 6)
   4        1         1   315.834   315.834
   1    StressPeriod:   7 (Day 7)
   4        1         1   316.387   316.387
   1    StressPeriod:   8 (Day 8)
   4        1         1   316.807   316.807
   1    StressPeriod:   9 (Day 9)
   4        1         1   316.721   316.721
   1    StressPeriod:   10 (Day 10)
   4        1         1   316.453   316.453
   1    StressPeriod:   11 (Day 11)
   4        1         1   316.122   316.122
   1    StressPeriod:   12 (Day 12)
   4        1         1   316.061   316.061
   1    StressPeriod:   13 (Day 13)
   4        1         1   316.102   316.102
   1    StressPeriod:   14 (Day 14)
   4        1         1   316.250   316.250
   1    StressPeriod:   15 (Day 15)
   4        1         1   316.524   316.524
   1    StressPeriod:   16 (Day 16)
   4        1         1   316.590   316.590
   1    StressPeriod:   17 (Day 17)
   4        1         1   316.949   316.949
   1    StressPeriod:   18 (Day 18)
   4        1         1   317.357   317.357
   1    StressPeriod:   19 (Day 19)
   4        1         1   317.633   317.633
   1    StressPeriod:   20 (Day 20)
   4        1         1   317.662   317.662
   1    StressPeriod:   21 (Day 21)
   4        1         1   317.692   317.692
   1    StressPeriod:   22 (Day 22)
   4        1         1   317.589   317.589
   1    StressPeriod:   23 (Day 23)
   4        1         1   317.525   317.525
   1    StressPeriod:   24 (Day 24)
   4        1         1   317.525   317.525
   1    StressPeriod:   25 (Day 25)
   4        1         1   317.382   317.382
   1    StressPeriod:   26 (Day 26)
   4        1         1   317.279   317.279
   1    StressPeriod:   27 (Day 27)
   4        1         1   317.176   317.176
   1    StressPeriod:   28 (Day 28)
   4        1         1   317.072   317.072
   1    StressPeriod:   29 (Day 29)
   4        1         1   317.072   317.072
   1    StressPeriod:   30 (Day 30)
   4        1         1   316.969   316.969
   1    StressPeriod:   31 (Day 31)
   4        1         1   316.959   316.959
```

```
1     StressPeriod:   32 (Day 32)
4         1         1   316.836   316.836
1     StressPeriod:   33 (Day 33)
4         1         1   316.723   316.723
1     StressPeriod:   34 (Day 34)
4         1         1   316.704   316.704
1     StressPeriod:   35 (Day 35)
4         1         1   316.662   316.662
1     StressPeriod:   36 (Day 36)
4         1         1   316.622   316.622
1     StressPeriod:   37 (Day 37)
4         1         1   316.511   316.511
1     StressPeriod:   38 (Day 38)
4         1         1   316.428   316.428
1     StressPeriod:   39 (Day 39)
4         1         1   316.255   316.255
1     StressPeriod:   40 (Day 40)
4         1         1   316.049   316.049
1     StressPeriod:   41 (Day 41)
4         1         1   315.780   315.780
1     StressPeriod:   42 (Day 42)
4         1         1   315.421   315.421
1     StressPeriod:   43 (Day 43)
4         1         1   315.013   315.013
1     StressPeriod:   44 (Day 44)
4         1         1   314.646   314.646
1     StressPeriod:   45 (Day 45)
4         1         1   314.173   314.173
1     StressPeriod:   46 (Day 46)
4         1         1   313.832   313.832
1     StressPeriod:   47 (Day 47)
4         1         1   313.532   313.532
1     StressPeriod:   48 (Day 48)
4         1         1   313.314   313.314
1     StressPeriod:   49 (Day 49)
4         1         1   313.195   313.195
1     StressPeriod:   50 (Day 50)
4         1         1   313.216   313.216
1     StressPeriod:   51 (Day 51)
4         1         1   313.187   313.187
1     StressPeriod:   52 (Day 52)
4         1         1   313.172   313.172
1     StressPeriod:   53 (Day 53)
4         1         1   313.157   313.157
1     StressPeriod:   54 (Day 54)
4         1         1   313.142   313.142
1     StressPeriod:   55 (Day 55)
4         1         1   313.127   313.127
1     StressPeriod:   56 (Day 56)
4         1         1   313.113   313.113
1     StressPeriod:   57 (Day 57)
4         1         1   313.098   313.098
1     StressPeriod:   58 (Day 58)
4         1         1   313.083   313.083
1     StressPeriod:   59 (Day 59)
4         1         1   313.068   313.068
1     StressPeriod:   60 (Day 60)
4         1         1   313.063   313.063
1     StressPeriod:   61 (Day 61)
4         1         1   313.057   313.057
1     StressPeriod:   62 (Day 62)
4         1         1   313.051   313.051
1     StressPeriod:   63 (Day 63)
4         1         1   313.045   313.045
1     StressPeriod:   64 (Day 64)
4         1         1   313.039   313.039
```

```
1     StressPeriod:   65 (Day 65)
4         1         1   313.039   313.039
1     StressPeriod:   66 (Day 66)
4         1         1   313.039   313.039
1     StressPeriod:   67 (Day 67)
4         1         1   313.039   313.039
1     StressPeriod:   68 (Day 68)
4         1         1   313.039   313.039
1     StressPeriod:   69 (Day 69)
4         1         1   313.039   313.039
1     StressPeriod:   70 (Day 70)
4         1         1   313.039   313.039
```

Table F-15 Input file for the Time-variant Specified Head (CHD) Package for the Baldhill Dam Pool Raise Simulation: With the Balhill Dam Pool Raise

```
1000 CHD input file for baseline conditions:
   1    StressPeriod:   1 (Day 1)
   4        1         1   313.108   313.108
   1    StressPeriod:   2 (Day 2)
   4        1         1   313.570   313.570
   1    StressPeriod:   3 (Day 3)
   4        1         1   313.730   313.730
   1    StressPeriod:   4 (Day 4)
   4        1         1   314.216   314.216
   1    StressPeriod:   5 (Day 5)
   4        1         1   314.912   314.912
   1    StressPeriod:   6 (Day 6)
   4        1         1   315.834   315.834
   1    StressPeriod:   7 (Day 7)
   4        1         1   316.387   316.387
   1    StressPeriod:   8 (Day 8)
   4        1         1   316.807   316.807
   1    StressPeriod:   9 (Day 9)
   4        1         1   316.721   316.721
   1    StressPeriod:   10 (Day 10)
   4        1         1   316.453   316.453
   1    StressPeriod:   11 (Day 11)
   4        1         1   316.122   316.122
   1    StressPeriod:   12 (Day 12)
   4        1         1   316.081   316.081
   1    StressPeriod:   13 (Day 13)
   4        1         1   316.143   316.143
   1    StressPeriod:   14 (Day 14)
   4        1         1   316.374   316.374
   1    StressPeriod:   15 (Day 15)
   4        1         1   316.585   316.585
   1    StressPeriod:   16 (Day 16)
   4        1         1   316.743   316.743
   1    StressPeriod:   17 (Day 17)
   4        1         1   316.998   316.998
   1    StressPeriod:   18 (Day 18)
   4        1         1   317.048   317.048
   1    StressPeriod:   19 (Day 19)
   4        1         1   317.117   317.117
   1    StressPeriod:   20 (Day 20)
   4        1         1   317.146   317.146
   1    StressPeriod:   21 (Day 21)
   4        1         1   317.156   317.156
   1    StressPeriod:   22 (Day 22)
   4        1         1   317.156   317.156
   1    StressPeriod:   23 (Day 23)
   4        1         1   317.166   317.166
   1    StressPeriod:   24 (Day 24)
   4        1         1   317.156   317.156
   1    StressPeriod:   25 (Day 25)
   4        1         1   317.156   317.156
   1    StressPeriod:   26 (Day 26)
   4        1         1   317.156   317.156
   1    StressPeriod:   27 (Day 27)
```

```
4        1         1   317.156   317.156
1    StressPeriod:   28 (Day 28)
4        1         1   317.156   317.156
1    StressPeriod:   29 (Day 29)
4        1         1   317.156   317.156
1    StressPeriod:   30 (Day 30)
4        1         1   317.156   317.156
1    StressPeriod:   31 (Day 31)
4        1         1   317.053   317.053
1    StressPeriod:   32 (Day 32)
4        1         1   317.053   317.053
1    StressPeriod:   33 (Day 33)
4        1         1   317.043   317.043
1    StressPeriod:   34 (Day 34)
4        1         1   317.043   317.043
1    StressPeriod:   35 (Day 35)
4        1         1   316.940   316.940
1    StressPeriod:   36 (Day 36)
4        1         1   316.940   316.940
1    StressPeriod:   37 (Day 37)
4        1         1   316.930   316.930
1    StressPeriod:   38 (Day 38)
4        1         1   316.826   316.826
1    StressPeriod:   39 (Day 39)
4        1         1   316.704   316.704
1    StressPeriod:   40 (Day 40)
4        1         1   316.662   316.662
1    StressPeriod:   41 (Day 41)
4        1         1   316.333   316.333
1    StressPeriod:   42 (Day 42)
4        1         1   315.850   315.850
1    StressPeriod:   43 (Day 43)
4        1         1   315.416   315.416
1    StressPeriod:   44 (Day 44)
4        1         1   314.926   314.926
1    StressPeriod:   45 (Day 45)
4        1         1   314.489   314.489
1    StressPeriod:   46 (Day 46)
4        1         1   314.049   314.049
1    StressPeriod:   47 (Day 47)
4        1         1   313.684   313.684
1    StressPeriod:   48 (Day 48)
4        1         1   313.529   313.529
1    StressPeriod:   49 (Day 49)
4        1         1   313.422   313.422
1    StressPeriod:   50 (Day 50)
4        1         1   313.401   313.401
1    StressPeriod:   51 (Day 51)
4        1         1   313.367   313.367
1    StressPeriod:   52 (Day 52)
4        1         1   313.351   313.351
1    StressPeriod:   53 (Day 53)
4        1         1   313.334   313.334
1    StressPeriod:   54 (Day 54)
4        1         1   313.317   313.317
1    StressPeriod:   55 (Day 55)
4        1         1   313.301   313.301
1    StressPeriod:   56 (Day 56)
4        1         1   313.284   313.284
```

```
1    StressPeriod:   57 (Day 57)
4         1         1   313.267   313.267
1    StressPeriod:   58 (Day 58)
4         1         1   313.250   313.250
1    StressPeriod:   59 (Day 59)
4         1         1   313.234   313.234
1    StressPeriod:   60 (Day 60)
4         1         1   313.228   313.228
1    StressPeriod:   61 (Day 61)
4         1         1   313.222   313.222
1    StressPeriod:   62 (Day 62)
4         1         1   313.216   313.216
1    StressPeriod:   63 (Day 63)
4         1         1   313.210   313.210
1    StressPeriod:   64 (Day 64)
4         1         1   313.204   313.204
1    StressPeriod:   65 (Day 65)
4         1         1   313.204   313.204
1    StressPeriod:   66 (Day 66)
4         1         1   313.204   313.204
1    StressPeriod:   67 (Day 67)
4         1         1   313.204   313.204
1    StressPeriod:   68 (Day 68)
4         1         1   313.204   313.204
1    StressPeriod:   69 (Day 69)
4         1         1   313.204   313.204
1    StressPeriod:   70 (Day 70)
4         1         1   313.204   313.204
```

Table F-16 Volumetric Budget Output for the Steady-state Model at Cross-section 2

```
 VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  1 IN STRESS PERIOD  1
 -----------------------------------------------------------------------------

    CUMULATIVE VOLUMES      L**3       RATES FOR THIS TIME STEP      L**3/T
    ------------------                 ------------------------

          IN:                                   IN:
          ---                                   ---
        CONSTANT HEAD =           0.0000         CONSTANT HEAD =           0.0000
               DRAINS =           0.0000                DRAINS =           0.0000
                   ET =           0.0000                    ET =           0.0000
             RECHARGE =           3.8698              RECHARGE =           3.8698

             TOTAL IN =           3.8698              TOTAL IN =           3.8698

         OUT:                                  OUT:
         ----                                  ----
        CONSTANT HEAD =           1.8010         CONSTANT HEAD =           1.8010
               DRAINS =           0.0000                DRAINS =           0.0000
                   ET =           2.0694                    ET =           2.0694
             RECHARGE =           0.0000              RECHARGE =           0.0000

            TOTAL OUT =           3.8704             TOTAL OUT =           3.8704

             IN - OUT =      -5.9319E-04              IN - OUT =      -5.9319E-04

  PERCENT DISCREPANCY =          -0.02     PERCENT DISCREPANCY =          -0.02
```

Table F-17 Volumetric Budget Output for the Transient Model of a 100-year Flood with the Baldhill Pool Raise at Cross-section 2 (70 stress periods of 1 day each)

```
VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD  1

-----------------------------------------------------------------------------
      CUMULATIVE VOLUMES      L**3    RATES FOR THIS TIME STEP      L**3/T
      ------------------              ------------------------

               IN:                                     IN:
               ---                                     ---
            STORAGE =    2.7078                     STORAGE =    2.4973
      CONSTANT HEAD =   0.00000               CONSTANT HEAD =   0.00000
               ELLS =   0.00000                       WELLS =   0.00000
             DRAINS =   0.00000                      DRAINS =   0.00000
           RECHARGE =    21.404                    RECHARGE =    21.404
                 ET =   0.00000                          ET =   0.00000

           TOTAL IN =    24.112                    TOTAL IN =    23.901

              OUT:                                    OUT:
              ----                                    ----
            STORAGE =    11.861                     STORAGE =    11.658
      CONSTANT HEAD =   0.42313               CONSTANT HEAD =   0.40567
              WELLS =   0.00000                       WELLS =   0.00000
             DRAINS =   0.00000                      DRAINS =   0.00000
           RECHARGE =   0.00000                    RECHARGE =   0.00000
                 ET =    11.804                          ET =    11.815

          TOTAL OUT =    24.088                   TOTAL OUT =    23.878

           IN - OUT =   0.23767E-01                IN - OUT =   0.22823E-01

PERCENT DISCREPANCY =      0.10         PERCENT DISCREPANCY =      0.10
```

```
VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD  2
-----------------------------------------------------------------------------

      CUMULATIVE VOLUMES      L**3            RATES FOR THIS TIME STEP      L**3/T
      ------------------                      ------------------------

             IN:                                     IN:
             ---                                     ---
            STORAGE =    4.9614                  STORAGE =    2.2127
      CONSTANT HEAD =   0.00000            CONSTANT HEAD =   0.00000
              WELLS =   0.00000                    WELLS =   0.00000
             DRAINS =   0.00000                   DRAINS =   0.00000
           RECHARGE =    42.808                 RECHARGE =    21.404
                 ET =   0.00000                       ET =   0.00000
           TOTAL IN =    47.769                 TOTAL IN =    23.617

            OUT:                                    OUT:
            ----                                    ----
            STORAGE =    23.609                  STORAGE =    11.685
      CONSTANT HEAD =   0.48096            CONSTANT HEAD =   0.70536E-01
              WELLS =   0.00000                    WELLS =   0.00000
             DRAINS =   0.00000                   DRAINS =   0.00000
           RECHARGE =   0.00000                 RECHARGE =   0.00000
                 ET =    23.639                       ET =    11.846
          TOTAL OUT =    47.729                TOTAL OUT =    23.601
           IN - OUT =   0.39852E-01             IN - OUT =   0.15114E-01
PERCENT DISCREPANCY =      0.08      PERCENT DISCREPANCY =      0.06
```

```
VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD  3
-----------------------------------------------------------------------------
```

```
      CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
      ------------------                     ------------------------

             IN:                                      IN:
             ---                                      ---
            STORAGE =    7.1183                      STORAGE =    2.1287
      CONSTANT HEAD =   0.43323E-01            CONSTANT HEAD =   0.34135E-01
              WELLS =   0.00000                        WELLS =   0.00000
             DRAINS =   0.00000                       DRAINS =   0.00000
           RECHARGE =    64.211                     RECHARGE =    21.404
                 ET =   0.00000                           ET =   0.00000
           TOTAL IN =    71.373                     TOTAL IN =    23.567

             OUT:                                     OUT:
             ----                                     ----
            STORAGE =    35.322                      STORAGE =    11.667
      CONSTANT HEAD =   0.48096                CONSTANT HEAD =   0.00000
              WELLS =   0.00000                        WELLS =   0.00000
             DRAINS =   0.00000                       DRAINS =   0.00000
           RECHARGE =   0.00000                     RECHARGE =   0.00000
                 ET =    35.505                           ET =    11.876
          TOTAL OUT =    71.308                    TOTAL OUT =    23.544
           IN - OUT =   0.65155E-01                 IN - OUT =   0.23079E-01
PERCENT DISCREPANCY =   0.09             PERCENT DISCREPANCY =      0.10

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD  4
-----------------------------------------------------------------------------

      CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
      ------------------                     ------------------------

             IN:                                      IN:
             ---                                      ---
            STORAGE =    9.1810                      STORAGE =    2.0402
        NSTANT HEAD =   0.44996                CONSTANT HEAD =   0.38443
              WELLS =   0.00000                        WELLS =   0.00000
             DRAINS =   0.00000                       DRAINS =   0.00000
           RECHARGE =    85.615                     RECHARGE =    21.404
                 ET =   0.00000                           ET =   0.00000
           TOTAL IN =    95.246                     TOTAL IN =    23.828

            OUT:                                     OUT:
            ----                                     ----
            STORAGE =    47.278                      STORAGE =    11.895
      CONSTANT HEAD =   0.48096                CONSTANT HEAD =   0.00000
              WELLS =   0.00000                        WELLS =   0.00000
             DRAINS =   0.00000                       DRAINS =   0.00000
           RECHARGE =   0.00000                     RECHARGE =   0.00000
                 ET =    47.403                           ET =    11.908
          TOTAL OUT =    95.161                    TOTAL OUT =    23.803
           IN - OUT =   0.84869E-01                 IN - OUT =   0.25652E-01
PERCENT DISCREPANCY =      0.09          PERCENT DISCREPANCY =      0.11

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD  5
-----------------------------------------------------------------------------

      CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
      ------------------                     ------------------------

             IN:                                      IN:
             ---                                      ---
            STORAGE =    11.191                      STORAGE =    1.9937
      CONSTANT HEAD =    1.3896                CONSTANT HEAD =   0.90383
              WELLS =   0.00000                        WELLS =   0.00000
             DRAINS =   0.00000                       DRAINS =   0.00000
           RECHARGE =    107.02                     RECHARGE =    21.404
                 ET =   0.00000                           ET =   0.00000
           TOTAL IN =    119.60                     TOTAL IN =    24.301

             OUT:                                     OUT:
             ----                                     ----
            STORAGE =    59.677                      STORAGE =    12.335
```

```
      CONSTANT HEAD =   0.48096              CONSTANT HEAD =   0.00000
              WELLS =   0.00000                      WELLS =   0.00000
             DRAINS =   0.00000                     DRAINS =   0.00000
           RECHARGE =   0.00000                   RECHARGE =   0.00000
                 ET =    59.331                         ET =    11.939
          TOTAL OUT =    119.49                  TOTAL OUT =    24.274
           IN - OUT =   0.10998                   IN - OUT =   0.27246E-01
PERCENT DISCREPANCY =      0.09        PERCENT DISCREPANCY =      0.11


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD  6
-----------------------------------------------------------------------------

      CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
      ------------------                     ------------------------

             IN:                                       IN:
             ---                                       ---
            STORAGE =    13.152                    STORAGE =    1.9506
      CONSTANT HEAD =    3.0165              CONSTANT HEAD =    1.5760
              WELLS =   0.00000                      WELLS =   0.00000
             DRAINS =   0.00000                     DRAINS =   0.00000
           RECHARGE =    128.42                   RECHARGE =    21.404
                 ET =   0.00000                         ET =   0.00000
           TOTAL IN =    144.59                   TOTAL IN =    24.930

            OUT:                                      OUT:
            ----                                      ----
            STORAGE =    72.690                    STORAGE =    12.945
      CONSTANT HEAD =   0.48096              CONSTANT HEAD =   0.00000
              WELLS =   0.00000                      WELLS =   0.00000
             DRAINS =   0.00000                     DRAINS =   0.00000
           RECHARGE =   0.00000                   RECHARGE =   0.00000
                 ET =    71.291                         ET =    11.970
          TOTAL OUT =    144.46                  TOTAL OUT =    24.915
           IN - OUT =   0.12944                   IN - OUT =   0.15604E-01
 ERCENT DISCREPANCY =      0.09        PERCENT DISCREPANCY =      0.06


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD  7
-----------------------------------------------------------------------------

      CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
      ------------------                     ------------------------

             IN:                                       IN:
             ---                                       ---
            STORAGE =    15.070                    STORAGE =    1.9009
      CONSTANT HEAD =    4.9922              CONSTANT HEAD =    1.9281
              WELLS =   0.00000                      WELLS =   0.00000
             DRAINS =   0.00000                     DRAINS =   0.00000
           RECHARGE =    149.83                   RECHARGE =    21.404
                 ET =   0.00000                         ET =   0.00000
           TOTAL IN =    169.89                   TOTAL IN =    25.233

            OUT:                                      OUT:
            ----                                      ----
            STORAGE =    85.980                    STORAGE =    13.210
      CONSTANT HEAD =   0.48096              CONSTANT HEAD =   0.00000
              WELLS =   0.00000                      WELLS =   0.00000
             DRAINS =   0.00000                     DRAINS =   0.00000
           RECHARGE =   0.00000                   RECHARGE =   0.00000
                 ET =    83.281                         ET =    12.000
          TOTAL OUT =    169.74                  TOTAL OUT =    25.211
           IN - OUT =   0.14754                   IN - OUT =   0.22200E-01
PERCENT DISCREPANCY =      0.09        PERCENT DISCREPANCY =      0.09


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD  8
-----------------------------------------------------------------------------

      CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
      ------------------                     ------------------------
```

```
            IN:                                      IN:
            ---                                      ---
           STORAGE =    16.945                     STORAGE =    1.8567
     CONSTANT HEAD =    7.2053               CONSTANT HEAD =    2.1659
             WELLS =   0.00000                       WELLS =   0.00000
            DRAINS =   0.00000                      DRAINS =   0.00000
          RECHARGE =    171.23                    RECHARGE =    21.404
                ET =   0.00000                          ET =   0.00000
          TOTAL IN =    195.38                    TOTAL IN =    25.426

            OUT:                                     OUT:
            ----                                     ----
           STORAGE =    99.427                     STORAGE =    13.367
     CONSTANT HEAD =   0.48096              CONSTANT HEAD =   0.00000
             WELLS =   0.00000                       WELLS =   0.00000
            DRAINS =   0.00000                      DRAINS =   0.00000
          RECHARGE =   0.00000                    RECHARGE =   0.00000
                ET =    95.302                          ET =    12.031
         TOTAL OUT =    195.21                   TOTAL OUT =    25.399
          IN - OUT =   0.17090                    IN - OUT =   0.27557E-01
PERCENT DISCREPANCY =      0.09          PERCENT DISCREPANCY =      0.11

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD  9
-----------------------------------------------------------------------------

      CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
      ------------------                     ------------------------

            IN:                                      IN:
            ---                                      ---
           STORAGE =    18.783                     STORAGE =    1.8302
     CONSTANT HEAD =    9.2243               CONSTANT HEAD =    1.9864
             WELLS =   0.00000                       WELLS =   0.00000
            DRAINS =   0.00000                      DRAINS =   0.00000
          RECHARGE =    192.63                    RECHARGE =    21.404
                ET =   0.00000                          ET =   0.00000
          TOTAL IN =    220.64                    TOTAL IN =    25.220

            OUT:                                     OUT:
            ----                                     ----
           STORAGE =    112.61                     STORAGE =    13.138
     CONSTANT HEAD =   0.48096              CONSTANT HEAD =   0.00000
             WELLS =   0.00000                       WELLS =   0.00000
            DRAINS =   0.00000                      DRAINS =   0.00000
          RECHARGE =   0.00000                    RECHARGE =   0.00000
                ET =    107.35                          ET =    12.062
         TOTAL OUT =    220.45                   TOTAL OUT =    25.200
          IN - OUT =   0.19170                    IN - OUT =   0.20081E-01
PERCENT DISCREPANCY =      0.09          PERCENT DISCREPANCY =      0.08

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 10
-----------------------------------------------------------------------------

      CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
      ------------------                     ------------------------

            IN:                                      IN:
            ---                                      ---
           STORAGE =    20.601                     STORAGE =    1.8053
     CONSTANT HEAD =    10.917              CONSTANT HEAD =    1.6708
             WELLS =   0.00000                       WELLS =   0.00000
            DRAINS =   0.00000                      DRAINS =   0.00000
          RECHARGE =    214.04                    RECHARGE =    21.404
                ET =   0.00000                          ET =   0.00000
          TOTAL IN =    245.56                    TOTAL IN =    24.880

           OUT:                                     OUT:
           ----                                     ----
           STORAGE =    125.42                     STORAGE =    12.761
     CONSTANT HEAD =   0.48096              CONSTANT HEAD =   0.00000
             WELLS =   0.00000                       WELLS =   0.00000
            DRAINS =   0.00000                      DRAINS =   0.00000
```

```
           RECHARGE =   0.00000                       RECHARGE =   0.00000
                 ET =    119.44                             ET =    12.093
          TOTAL OUT =    245.34                      TOTAL OUT =    24.853
           IN - OUT =   0.21721                       IN - OUT =   0.26577E-01
PERCENT DISCREPANCY =      0.09            PERCENT DISCREPANCY =      0.11


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 11
-----------------------------------------------------------------------------

      CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
      ------------------                     ------------------------

             IN:                                      IN:
             ---                                      ---
            STORAGE =    22.399                        STORAGE =    1.7835
       INSTANT HEAD =    12.252                  CONSTANT HEAD =    1.3222
              WELLS =   0.00000                          WELLS =   0.00000
             DRAINS =   0.00000                         DRAINS =   0.00000
           RECHARGE =    235.44                       RECHARGE =    21.404
                 ET =   0.00000                             ET =   0.00000
           TOTAL IN =    270.09                       TOTAL IN =    24.509

            OUT:                                     OUT:
            ----                                     ----
            STORAGE =    137.82                        STORAGE =    12.370
      CONSTANT HEAD =   0.48096                  CONSTANT HEAD =   0.00000
              WELLS =   0.00000                          WELLS =   0.00000
             DRAINS =   0.00000                         DRAINS =   0.00000
           RECHARGE =   0.00000                       RECHARGE =   0.00000
                 ET =    131.55                             ET =    12.123
          TOTAL OUT =    269.85                      TOTAL OUT =    24.492
           IN - OUT =   0.23990                       IN - OUT =   0.17290E-01
PERCENT DISCREPANCY =      0.09            PERCENT DISCREPANCY =      0.07


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 12
-----------------------------------------------------------------------------

      CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
      ------------------                     ------------------------

             IN:                                      IN:
             ---                                      ---
            STORAGE =    24.162                        STORAGE =    1.7549
      CONSTANT HEAD =    13.502                  CONSTANT HEAD =    1.2332
              WELLS =   0.00000                          WELLS =   0.00000
             DRAINS =   0.00000                         DRAINS =   0.00000
           RECHARGE =    256.85                       RECHARGE =    21.404
                 ET =   0.00000                             ET =   0.00000
           TOTAL IN =    294.51                       TOTAL IN =    24.392

            OUT:                                     OUT:
            ----                                     ----
            STORAGE =    150.08                        STORAGE =    12.225
      CONSTANT HEAD =   0.48096                  CONSTANT HEAD =   0.00000
              WELLS =   0.00000                          WELLS =   0.00000
             DRAINS =   0.00000                         DRAINS =   0.00000
           RECHARGE =   0.00000                       RECHARGE =   0.00000
                 ET =    143.69                             ET =    12.152
          TOTAL OUT =    294.25                      TOTAL OUT =    24.378
           IN - OUT =   0.26117                       IN - OUT =   0.13985E-01
PERCENT DISCREPANCY =      0.09            PERCENT DISCREPANCY =      0.06


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 13
-----------------------------------------------------------------------------

      CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
      ------------------                     ------------------------

             IN:                                      IN:
             ---                                      ---
```

```
              STORAGE =    25.894                 STORAGE =    1.7240
        CONSTANT HEAD =    14.756           CONSTANT HEAD =    1.2351
                WELLS =   0.00000                   WELLS =   0.00000
               DRAINS =   0.00000                  DRAINS =   0.00000
             RECHARGE =    278.25                RECHARGE =    21.404
                   ET =   0.00000                      ET =   0.00000
             TOTAL IN =    318.90                TOTAL IN =    24.363

            OUT:                         OUT:
            ----                         ----
              STORAGE =    162.27                 STORAGE =    12.154
        CONSTANT HEAD =   0.48096           CONSTANT HEAD =   0.00000
                WELLS =   0.00000                   WELLS =   0.00000
               DRAINS =   0.00000                  DRAINS =   0.00000
             RECHARGE =   0.00000                RECHARGE =   0.00000
                   ET =    155.86                      ET =    12.183
            TOTAL OUT =    318.62               TOTAL OUT =    24.337
             IN - OUT =   0.28223                IN - OUT =   0.25541E-01
  PERCENT DISCREPANCY =      0.09     PERCENT DISCREPANCY =      0.10


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 14
-----------------------------------------------------------------------------

       CUMULATIVE VOLUMES      L**3         RATES FOR THIS TIME STEP      L**3/T
       ------------------                   ------------------------

             IN:                                  IN:
             ---                                  ---
              STORAGE =    27.605                 STORAGE =    1.7051
        CONSTANT HEAD =    16.158           CONSTANT HEAD =    1.3784
                WELLS =   0.00000                   WELLS =   0.00000
               DRAINS =   0.00000                  DRAINS =   0.00000
             RECHARGE =    299.65                RECHARGE =    21.404
                   ET =   0.00000                      ET =   0.00000
             TOTAL IN =    343.42                TOTAL IN =    24.487

            OUT:                         OUT:
            ----                         ----
              STORAGE =    174.56                 STORAGE =    12.242
        CONSTANT HEAD =   0.48096           CONSTANT HEAD =   0.00000
                WELLS =   0.00000                   WELLS =   0.00000
               DRAINS =   0.00000                  DRAINS =   0.00000
             RECHARGE =   0.00000                RECHARGE =   0.00000
                   ET =    168.07                      ET =    12.213
            TOTAL OUT =    343.11               TOTAL OUT =    24.456
             IN - OUT =   0.31000                IN - OUT =   0.31467E-01
  PERCENT DISCREPANCY =      0.09     PERCENT DISCREPANCY =      0.13


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 15
-----------------------------------------------------------------------------

        CUMULATIVE VOLUMES      L**3         RATES FOR THIS TIME STEP      L**3/T
        ------------------                   ------------------------

             IN:                                  IN:
             ---                                  ---
              STORAGE =    29.290                 STORAGE =    1.6797
        CONSTANT HEAD =    17.683           CONSTANT HEAD =    1.4991
                WELLS =   0.00000                   WELLS =   0.00000
               DRAINS =   0.00000                  DRAINS =   0.00000
             RECHARGE =    321.06                RECHARGE =    21.404
                   ET =   0.00000                      ET =   0.00000
             TOTAL IN =    368.03                TOTAL IN =    24.583

            OUT:                         OUT:
            ----                         ----
              STORAGE =    186.92                 STORAGE =    12.321
        CONSTANT HEAD =   0.48096           CONSTANT HEAD =   0.00000
                WELLS =   0.00000                   WELLS =   0.00000
               DRAINS =   0.00000                  DRAINS =   0.00000
```

```
                 RECHARGE =   0.00000                RECHARGE =   0.00000
                       ET =    180.30                      ET =    12.244
                TOTAL OUT =    367.70               TOTAL OUT =    24.565
                 IN - OUT =   0.33142                IN - OUT =   0.17864E-01
      PERCENT DISCREPANCY =      0.09     PERCENT DISCREPANCY =      0.07


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 16
-----------------------------------------------------------------------------

          CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
          ------------------                     ------------------------

                IN:                                      IN:
                ---                                      ---
                  STORAGE =    30.950                 STORAGE =    1.6543
            CONSTANT HEAD =    19.280           CONSTANT HEAD =    1.5714
                    WELLS =   0.00000                   WELLS =   0.00000
                   DRAINS =   0.00000                  DRAINS =   0.00000
                 RECHARGE =    342.46                RECHARGE =    21.404
                       ET =   0.00000                      ET =   0.00000
                 TOTAL IN =    392.69                TOTAL IN =    24.630

               OUT:                                     OUT:
               ----                                     ----
                  STORAGE =    199.29                 STORAGE =    12.323
            CONSTANT HEAD =   0.48096           CONSTANT HEAD =   0.00000
                    WELLS =   0.00000                   WELLS =   0.00000
                   DRAINS =   0.00000                  DRAINS =   0.00000
                 RECHARGE =   0.00000                RECHARGE =   0.00000
                       ET =    192.57                      ET =    12.274
                TOTAL OUT =    392.33               TOTAL OUT =    24.597
                 IN - OUT =   0.35666                IN - OUT =   0.32598E-01
      PERCENT DISCREPANCY =      0.09     PERCENT DISCREPANCY =      0.13


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 17
-----------------------------------------------------------------------------

          CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
          ------------------                     ------------------------

                IN:                                      IN:
                ---                                      ---
                  STORAGE =    32.586                 STORAGE =    1.6288
            CONSTANT HEAD =    20.584           CONSTANT HEAD =    1.1703
                    WELLS =   0.00000                   WELLS =   0.00000
                   DRAINS =   0.00000                  DRAINS =   0.00000
                 RECHARGE =    363.86                RECHARGE =    21.404
                       ET =   0.00000                      ET =   0.00000
                 TOTAL IN =    417.04                TOTAL IN =    24.203

               OUT:                                     OUT:
               ----                                     ----
                  STORAGE =    211.31                 STORAGE =    11.877
            CONSTANT HEAD =   0.48096           CONSTANT HEAD =   0.00000
                    WELLS =   0.00000                   WELLS =   0.00000
                   DRAINS =   0.00000                  DRAINS =   0.00000
                 RECHARGE =   0.00000                RECHARGE =   0.00000
                       ET =    204.86                      ET =    12.304
                TOTAL OUT =    416.65               TOTAL OUT =    24.181
                 IN - OUT =   0.38071                IN - OUT =   0.22167E-01
      PERCENT DISCREPANCY =      0.09     PERCENT DISCREPANCY =      0.09


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 18
-----------------------------------------------------------------------------

          CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
          ------------------                     ------------------------
```

```
                IN:                                       IN:
                ---                                       ---
                  STORAGE =     34.205                      STORAGE =     1.6144
            CONSTANT HEAD =     21.752                CONSTANT HEAD =     1.1550
                    WELLS =    0.00000                        WELLS =    0.00000
                   DRAINS =    0.00000                       DRAINS =    0.00000
                 RECHARGE =     385.27                     RECHARGE =     21.404
                       ET =    0.00000                           ET =    0.00000
                 TOTAL IN =     441.23                     TOTAL IN =     24.173

               OUT:                                      OUT:
               ----                                      ----
                  STORAGE =     223.15                      STORAGE =     11.810
            CONSTANT HEAD =    0.48096                CONSTANT HEAD =    0.00000
                    WELLS =    0.00000                        WELLS =    0.00000
                   DRAINS =    0.00000                       DRAINS =    0.00000
                 RECHARGE =    0.00000                     RECHARGE =    0.00000
                       ET =     217.18                           ET =     12.334
                TOTAL OUT =     440.81                    TOTAL OUT =     24.144
                 IN - OUT =    0.41248                     IN - OUT =    0.29543E-01
      PERCENT DISCREPANCY =       0.09          PERCENT DISCREPANCY =       0.12


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 19
-----------------------------------------------------------------------------

          CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
          ------------------                     ------------------------

                IN:                                       IN:
                ---                                       ---
                  STORAGE =     35.805                      STORAGE =     1.5989
            CONSTANT HEAD =     22.919                CONSTANT HEAD =     1.1543
                    WELLS =    0.00000                        WELLS =    0.00000
                   DRAINS =    0.00000                       DRAINS =    0.00000
                 RECHARGE =     406.67                     RECHARGE =     21.404
                       ET =    0.00000                           ET =    0.00000
                 TOTAL IN =     465.40                     TOTAL IN =     24.157

               OUT:                                      OUT:
               ----                                      ----
                  STORAGE =     234.95                      STORAGE =     11.774
            CONSTANT HEAD =    0.48096                CONSTANT HEAD =    0.00000
                    WELLS =    0.00000                        WELLS =    0.00000
                   DRAINS =    0.00000                       DRAINS =    0.00000
                 RECHARGE =    0.00000                     RECHARGE =    0.00000
                       ET =     229.54                           ET =     12.363
                TOTAL OUT =     464.97                    TOTAL OUT =     24.137
                 IN - OUT =    0.43179                     IN - OUT =    0.19791E-01
      PERCENT DISCREPANCY =       0.09          PERCENT DISCREPANCY =       0.08


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 20
-----------------------------------------------------------------------------

          CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
          ------------------                     ------------------------

                IN:                                       IN:
                ---                                       ---
                  STORAGE =     37.393                      STORAGE =     1.5790
            CONSTANT HEAD =     24.068                CONSTANT HEAD =     1.1375
                    WELLS =    0.00000                        WELLS =    0.00000
                   DRAINS =    0.00000                       DRAINS =    0.00000
                 RECHARGE =     428.08                     RECHARGE =     21.404
                       ET =    0.00000                           ET =    0.00000
                 TOTAL IN =     489.54                     TOTAL IN =     24.120

               OUT:                                      OUT:
               ----                                      ----
                  STORAGE =     246.68                      STORAGE =     11.704
            CONSTANT HEAD =    0.48096                CONSTANT HEAD =    0.00000
```

```
                 WELLS =   0.00000                     WELLS =   0.00000
                DRAINS =   0.00000                    DRAINS =   0.00000
              RECHARGE =   0.00000                  RECHARGE =   0.00000
                    ET =    241.92                        ET =    12.392
             TOTAL OUT =    489.08                 TOTAL OUT =    24.096
              IN - OUT =   0.45694                  IN - OUT =   0.24223E-01
   PERCENT DISCREPANCY =      0.09       PERCENT DISCREPANCY =      0.10


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 21
-----------------------------------------------------------------------------

   CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
   ------------------                     ------------------------

          IN:                                      IN:
          ---                                      ---
               STORAGE =    38.966                   STORAGE =    1.5679
         CONSTANT HEAD =    25.191             CONSTANT HEAD =    1.1143
                 WELLS =   0.00000                     WELLS =   0.00000
                DRAINS =   0.00000                    DRAINS =   0.00000
              RECHARGE =    449.48                  RECHARGE =    21.404
                    ET =   0.00000                        ET =   0.00000
              TOTAL IN =    513.64                  TOTAL IN =    24.086

         OUT:                                     OUT:
         ----                                     ----
               STORAGE =    258.34                   STORAGE =    11.640
         CONSTANT HEAD =   0.48096             CONSTANT HEAD =   0.00000
                 WELLS =   0.00000                     WELLS =   0.00000
                DRAINS =   0.00000                    DRAINS =   0.00000
              RECHARGE =   0.00000                  RECHARGE =   0.00000
                    ET =    254.33                        ET =    12.421
             TOTAL OUT =    513.15                 TOTAL OUT =    24.061
              IN - OUT =   0.48688                  IN - OUT =   0.24759E-01
   PERCENT DISCREPANCY =      0.09       PERCENT DISCREPANCY =      0.10


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 22
-----------------------------------------------------------------------------

   CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
   ------------------                     ------------------------

          IN:                                      IN:
          ---                                      ---
               STORAGE =    40.522                   STORAGE =    1.5480
         CONSTANT HEAD =    26.288             CONSTANT HEAD =    1.0885
                 WELLS =   0.00000                     WELLS =   0.00000
                DRAINS =   0.00000                    DRAINS =   0.00000
              RECHARGE =    470.88                  RECHARGE =    21.404
                    ET =   0.00000                        ET =   0.00000
              TOTAL IN =    537.69                  TOTAL IN =    24.040

         OUT:                                     OUT:
         ----                                     ----
               STORAGE =    269.93                   STORAGE =    11.562
         CONSTANT HEAD =   0.48096             CONSTANT HEAD =   0.00000
                 WELLS =   0.00000                     WELLS =   0.00000
                DRAINS =   0.00000                    DRAINS =   0.00000
              RECHARGE =   0.00000                  RECHARGE =   0.00000
                    ET =    266.77                        ET =    12.449
             TOTAL OUT =    537.18                 TOTAL OUT =    24.011
              IN - OUT =   0.51306                  IN - OUT =   0.29202E-01
   PERCENT DISCREPANCY =      0.10       PERCENT DISCREPANCY =      0.12


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 23
-----------------------------------------------------------------------------

   CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
```

```
                  -----------------                       -----------------------

                        IN:                                      IN:
                        ---                                      ---
                          STORAGE =    42.063                      STORAGE =    1.5358
                    CONSTANT HEAD =    27.365                CONSTANT HEAD =    1.0691
                            WELLS =   0.00000                        WELLS =   0.00000
                           DRAINS =   0.00000                       DRAINS =   0.00000
                         RECHARGE =    492.29                     RECHARGE =    21.404
                               ET =   0.00000                           ET =   0.00000
                         TOTAL IN =    561.72                     TOTAL IN =    24.009

                       OUT:                                     OUT:
                       ----                                     ----
                          STORAGE =    281.46                      STORAGE =    11.509
                    CONSTANT HEAD =   0.48096                CONSTANT HEAD =   0.00000
                            WELLS =   0.00000                        WELLS =   0.00000
                           DRAINS =   0.00000                       DRAINS =   0.00000
                         RECHARGE =   0.00000                     RECHARGE =   0.00000
                               ET =    279.24                           ET =    12.478
                        TOTAL OUT =    561.18                    TOTAL OUT =    23.987
                         IN - OUT =   0.53619                     IN - OUT =   0.22099E-01
              PERCENT DISCREPANCY =       0.10         PERCENT DISCREPANCY =      0.09


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 24
-----------------------------------------------------------------------------

                  CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                  ------------------                     ------------------------

                        IN:                                      IN:
                        ---                                      ---
                          STORAGE =    43.590                      STORAGE =    1.5214
                    CONSTANT HEAD =    28.415                CONSTANT HEAD =    1.0421
                            WELLS =   0.00000                        WELLS =   0.00000
                           DRAINS =   0.00000                       DRAINS =   0.00000
                         RECHARGE =    513.69                     RECHARGE =    21.404
                               ET =   0.00000                           ET =   0.00000
                         TOTAL IN =    585.70                     TOTAL IN =    23.967

                       OUT:                                     OUT:
                       ----                                     ----
                          STORAGE =    292.92                      STORAGE =    11.438
                    CONSTANT HEAD =   0.48096                CONSTANT HEAD =   0.00000
                            WELLS =   0.00000                        WELLS =   0.00000
                           DRAINS =   0.00000                       DRAINS =   0.00000
                         RECHARGE =   0.00000                     RECHARGE =   0.00000
                               ET =    291.74                           ET =    12.506
                        TOTAL OUT =    585.14                    TOTAL OUT =    23.944
                         IN - OUT =   0.56061                     IN - OUT =   0.23428E-01
              PERCENT DISCREPANCY =      0.10          PERCENT DISCREPANCY =      0.10


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 25
-----------------------------------------------------------------------------

                  CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                  ------------------                     ------------------------

                        IN:                                      IN:
                        ---                                      ---
                          STORAGE =    45.102                      STORAGE =    1.5081
                    CONSTANT HEAD =    29.443                CONSTANT HEAD =    1.0213
                            WELLS =   0.00000                        WELLS =   0.00000
                           DRAINS =   0.00000                       DRAINS =   0.00000
                         RECHARGE =    535.10                     RECHARGE =    21.404
                               ET =   0.00000                           ET =   0.00000
                         TOTAL IN =    609.64                     TOTAL IN =    23.933

                       OUT:                                     OUT:
                       ----                                     ----
```

```
                 STORAGE =    304.30                    STORAGE =    11.371
           CONSTANT HEAD =   0.48096              CONSTANT HEAD =   0.00000
                   WELLS =   0.00000                      WELLS =   0.00000
                  DRAINS =   0.00000                     DRAINS =   0.00000
                RECHARGE =   0.00000                   RECHARGE =   0.00000
                      ET =    304.26                         ET =    12.534
               TOTAL OUT =    609.05                  TOTAL OUT =    23.906
                IN - OUT =   0.59290                   IN - OUT =   0.27557E-01
     PERCENT DISCREPANCY =      0.10        PERCENT DISCREPANCY =      0.12


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 26
-----------------------------------------------------------------------------

    CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
    ------------------                     ------------------------

          IN:                                      IN:
          ---                                      ---
                 STORAGE =    46.606                    STORAGE =    1.4992
           CONSTANT HEAD =    30.318              CONSTANT HEAD =   0.82398
                   WELLS =   0.00000                      WELLS =   0.00000
                  DRAINS =   0.00000                     DRAINS =   0.00000
                RECHARGE =    556.50                   RECHARGE =    21.404
                      ET =   0.00000                         ET =   0.00000
                TOTAL IN =    633.42                   TOTAL IN =    23.727

         OUT:                                     OUT:
         ----                                     ----
                 STORAGE =    315.51                    STORAGE =    11.134
           CONSTANT HEAD =   0.48096              CONSTANT HEAD =   0.00000
                   WELLS =   0.00000                      WELLS =   0.00000
                  DRAINS =   0.00000                     DRAINS =   0.00000
                RECHARGE =   0.00000                   RECHARGE =   0.00000
                      ET =    316.81                         ET =    12.562
               TOTAL OUT =    632.80                  TOTAL OUT =    23.696
                IN - OUT =   0.61920                   IN - OUT =   0.31097E-01
     PERCENT DISCREPANCY =      0.10        PERCENT DISCREPANCY =      0.13


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 27
-----------------------------------------------------------------------------

    CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
    ------------------                     ------------------------

          IN:                                      IN:
          ---                                      ---
                 STORAGE =    48.100                    STORAGE =    1.4948
           CONSTANT HEAD =    31.128              CONSTANT HEAD =   0.80473
                   WELLS =   0.00000                      WELLS =   0.00000
                  DRAINS =   0.00000                     DRAINS =   0.00000
                RECHARGE =    577.90                   RECHARGE =    21.404
                      ET =   0.00000                         ET =   0.00000
                TOTAL IN =    657.13                   TOTAL IN =    23.703

         OUT:                                     OUT:
         ----                                     ----
                 STORAGE =    326.62                    STORAGE =    11.091
           CONSTANT HEAD =   0.48096              CONSTANT HEAD =   0.00000
                   WELLS =   0.00000                      WELLS =   0.00000
                  DRAINS =   0.00000                     DRAINS =   0.00000
                RECHARGE =   0.00000                   RECHARGE =   0.00000
                      ET =    329.40                         ET =    12.590
               TOTAL OUT =    656.49                  TOTAL OUT =    23.682
                IN - OUT =   0.63818                   IN - OUT =   0.21620E-01
     PERCENT DISCREPANCY =      0.10        PERCENT DISCREPANCY =      0.09


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 28
-----------------------------------------------------------------------------
```

```
              CUMULATIVE VOLUMES      L**3          RATES FOR THIS TIME STEP      L**3/T
              ------------------                    ------------------------

                    IN:                                        IN:
                    ---                                        ---
                      STORAGE =    49.588                        STORAGE =    1.4849
                CONSTANT HEAD =    31.923                  CONSTANT HEAD =   0.79036
                        WELLS =   0.00000                          WELLS =   0.00000
                       DRAINS =   0.00000                         DRAINS =   0.00000
                     RECHARGE =    599.31                       RECHARGE =    21.404
                           ET =   0.00000                             ET =   0.00000
                     TOTAL IN =    680.82                       TOTAL IN =    23.679

                   OUT:                                       OUT:
                   ----                                       ----
                      STORAGE =    337.67                        STORAGE =    11.043
                CONSTANT HEAD =   0.48096                  CONSTANT HEAD =   0.00000
                        WELLS =   0.00000                          WELLS =   0.00000
                       DRAINS =   0.00000                         DRAINS =   0.00000
                     RECHARGE =   0.00000                       RECHARGE =   0.00000
                           ET =    342.00                             ET =    12.618
                    TOTAL OUT =    680.15                      TOTAL OUT =    23.661
                     IN - OUT =   0.66364                       IN - OUT =   0.18375E-01
          PERCENT DISCREPANCY =      0.10            PERCENT DISCREPANCY =      0.08


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 29
------------------------------------------------------------------------------

              CUMULATIVE VOLUMES      L**3          RATES FOR THIS TIME STEP      L**3/T
              ------------------                    ------------------------

                    IN:                                        IN:
                    ---                                        ---
                      STORAGE =    51.067                        STORAGE =    1.4782
                CONSTANT HEAD =    32.705                  CONSTANT HEAD =   0.77722
                        WELLS =   0.00000                          WELLS =   0.00000
                       DRAINS =   0.00000                         DRAINS =   0.00000
                     RECHARGE =    620.71                       RECHARGE =    21.404
                           ET =   0.00000                             ET =   0.00000
                     TOTAL IN =    704.48                       TOTAL IN =    23.659

                   OUT:                                       OUT:
                   ----                                       ----
                      STORAGE =    348.67                        STORAGE =    10.987
                CONSTANT HEAD =   0.48096                  CONSTANT HEAD =   0.00000
                        WELLS =   0.00000                          WELLS =   0.00000
                       DRAINS =   0.00000                         DRAINS =   0.00000
                     RECHARGE =   0.00000                       RECHARGE =   0.00000
                           ET =    354.64                             ET =    12.646
                    TOTAL OUT =    703.79                      TOTAL OUT =    23.633
                     IN - OUT =   0.68762                       IN - OUT =   0.26546E-01
          PERCENT DISCREPANCY =      0.10            PERCENT DISCREPANCY =      0.11

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 30
------------------------------------------------------------------------------

              CUMULATIVE VOLUMES      L**3          RATES FOR THIS TIME STEP      L**3/T
              ------------------                    ------------------------

                    IN:                                        IN:
                    ---                                        ---
                      STORAGE =    52.540                        STORAGE =    1.4705
                CONSTANT HEAD =    33.474                  CONSTANT HEAD =   0.76498
                        WELLS =   0.00000                          WELLS =   0.00000
                       DRAINS =   0.00000                         DRAINS =   0.00000
                     RECHARGE =    642.11                       RECHARGE =    21.404
                           ET =   0.00000                             ET =   0.00000
                     TOTAL IN =    728.13                       TOTAL IN =    23.639

                   OUT:                                       OUT:
                   ----                                       ----
```

```
                  STORAGE =    359.63                  STORAGE =    10.945
            CONSTANT HEAD =   0.48096            CONSTANT HEAD =   0.00000
                    WELLS =   0.00000                    WELLS =   0.00000
                   DRAINS =   0.00000                   DRAINS =   0.00000
                 RECHARGE =   0.00000                 RECHARGE =   0.00000
                       ET =    367.31                       ET =    12.675
                TOTAL OUT =    727.42                TOTAL OUT =    23.619
                 IN - OUT =   0.70825                 IN - OUT =   0.19855E-01
     PERCENT DISCREPANCY =       0.10      PERCENT DISCREPANCY =       0.08


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 31
-----------------------------------------------------------------------------

    CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
    ------------------                     ------------------------

          IN:                                      IN:
          ---                                      ---
                  STORAGE =    54.013                  STORAGE =    1.4678
            CONSTANT HEAD =    34.195            CONSTANT HEAD =   0.72134
                    WELLS =   0.00000                    WELLS =   0.00000
                   DRAINS =   0.00000                   DRAINS =   0.00000
                 RECHARGE =    663.52                 RECHARGE =    21.404
                       ET =   0.00000                       ET =   0.00000
                 TOTAL IN =    751.73                 TOTAL IN =    23.593

         OUT:                                     OUT:
         ----                                     ----
                  STORAGE =    370.51                  STORAGE =    10.865
            CONSTANT HEAD =   0.48096            CONSTANT HEAD =   0.00000
                    WELLS =   0.00000                    WELLS =   0.00000
                   DRAINS =   0.00000                   DRAINS =   0.00000
                 RECHARGE =   0.00000                 RECHARGE =   0.00000
                       ET =    380.00                       ET =    12.704
                TOTAL OUT =    750.99                TOTAL OUT =    23.569
                 IN - OUT =   0.73401                 IN - OUT =   0.23964E-01
     PERCENT DISCREPANCY =       0.10      PERCENT DISCREPANCY =       0.10


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 32
-----------------------------------------------------------------------------

    CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
    ------------------                     ------------------------

          IN:                                      IN:
          ---                                      ---
                  STORAGE =    55.478                  STORAGE =    1.4628
            CONSTANT HEAD =    34.910            CONSTANT HEAD =   0.71203
                    WELLS =   0.00000                    WELLS =   0.00000
                   DRAINS =   0.00000                   DRAINS =   0.00000
                 RECHARGE =    684.92                 RECHARGE =    21.404
                       ET =   0.00000                       ET =   0.00000
                 TOTAL IN =    775.31                 TOTAL IN =    23.579

         OUT:                                     OUT:
         ----                                     ----
                  STORAGE =    381.35                  STORAGE =    10.814
            CONSTANT HEAD =   0.48096            CONSTANT HEAD =   0.00000
                    WELLS =   0.00000                    WELLS =   0.00000
                   DRAINS =   0.00000                   DRAINS =   0.00000
                 RECHARGE =   0.00000                 RECHARGE =   0.00000
                       ET =    392.72                       ET =    12.732
                TOTAL OUT =    774.55                TOTAL OUT =    23.546
                 IN - OUT =   0.76056                 IN - OUT =   0.32505E-01
     PERCENT DISCREPANCY =       0.10      PERCENT DISCREPANCY =       0.14


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 33
-----------------------------------------------------------------------------
```

```
                    CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                    ------------------                     ------------------------

                          IN:                                      IN:
                          ---                                      ---
                            STORAGE =    56.937                      STORAGE =    1.4594
                      CONSTANT HEAD =    35.612                CONSTANT HEAD =   0.69944
                              WELLS =   0.00000                        WELLS =   0.00000
                             DRAINS =   0.00000                       DRAINS =   0.00000
                           RECHARGE =    706.33                     RECHARGE =    21.404
                                 ET =   0.00000                           ET =   0.00000
                           TOTAL IN =    798.87                     TOTAL IN =    23.563

                         OUT:                                     OUT:
                         ----                                     ----
                            STORAGE =    392.13                      STORAGE =    10.774
                      CONSTANT HEAD =   0.48096                CONSTANT HEAD =   0.00000
                              WELLS =   0.00000                        WELLS =   0.00000
                             DRAINS =   0.00000                       DRAINS =   0.00000
                           RECHARGE =   0.00000                     RECHARGE =   0.00000
                                 ET =    405.47                           ET =    12.760
                          TOTAL OUT =    798.09                    TOTAL OUT =    23.534
                           IN - OUT =   0.78723                     IN - OUT =   0.28593E-01
                PERCENT DISCREPANCY =      0.10          PERCENT DISCREPANCY =      0.12


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 34
-----------------------------------------------------------------------------

                    CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                    ------------------                     ------------------------

                          IN:                                      IN:
                          ---                                      ---
                            STORAGE =    58.388                      STORAGE =    1.4462
                      CONSTANT HEAD =    36.298                CONSTANT HEAD =   0.66831
                              WELLS =   0.00000                        WELLS =   0.00000
                             DRAINS =   0.00000                       DRAINS =   0.00000
                           RECHARGE =    727.73                     RECHARGE =    21.404
                                 ET =   0.00000                           ET =   0.00000
                           TOTAL IN =    822.41                     TOTAL IN =    23.518

                         OUT:                                     OUT:
                         ----                                     ----
                            STORAGE =    402.87                      STORAGE =    10.703
                      CONSTANT HEAD =   0.48096                CONSTANT HEAD =   0.00000
                              WELLS =   0.00000                        WELLS =   0.00000
                             DRAINS =   0.00000                       DRAINS =   0.00000
                           RECHARGE =   0.00000                     RECHARGE =   0.00000
                                 ET =    418.25                           ET =    12.788
                          TOTAL OUT =    821.60                    TOTAL OUT =    23.490
                           IN - OUT =   0.81360                     IN - OUT =   0.27958E-01
                PERCENT DISCREPANCY =      0.10          PERCENT DISCREPANCY =      0.12


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 35
-----------------------------------------------------------------------------

                    CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                    ------------------                     ------------------------

                          IN:                                      IN:
                          ---                                      ---
                            STORAGE =    59.838                      STORAGE =    1.4453
                      CONSTANT HEAD =    36.874                CONSTANT HEAD =   0.57283
                              WELLS =   0.00000                        WELLS =   0.00000
                             DRAINS =   0.00000                       DRAINS =   0.00000
                           RECHARGE =    749.13                     RECHARGE =    21.404
                                 ET =   0.00000                           ET =   0.00000
                           TOTAL IN =    845.84                     TOTAL IN =    23.422
```

```
                    OUT:                                     OUT:
                    ----                                     ----
                       STORAGE =    413.46                      STORAGE =    10.580
                 CONSTANT HEAD =   0.48096                CONSTANT HEAD =   0.00000
                         WELLS =   0.00000                        WELLS =   0.00000
                        DRAINS =   0.00000                       DRAINS =   0.00000
                      RECHARGE =   0.00000                     RECHARGE =   0.00000
                            ET =    431.06                           ET =    12.815
                     TOTAL OUT =    845.00                    TOTAL OUT =    23.395
                      IN - OUT =   0.84070                     IN - OUT =   0.27319E-01
           PERCENT DISCREPANCY =      0.10          PERCENT DISCREPANCY =      0.12


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 36
-----------------------------------------------------------------------------

                  CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                  ------------------                     ------------------------

                     IN:                                      IN:
                     ---                                      ---
                       STORAGE =    61.280                      STORAGE =    1.4406
                 CONSTANT HEAD =    37.441                CONSTANT HEAD =   0.56473
                         WELLS =   0.00000                        WELLS =   0.00000
                        DRAINS =   0.00000                       DRAINS =   0.00000
                      RECHARGE =    770.54                     RECHARGE =    21.404
                            ET =   0.00000                           ET =   0.00000
                      TOTAL IN =    869.26                     TOTAL IN =    23.409

                    OUT:                                     OUT:
                    ----                                     ----
                       STORAGE =    424.01                      STORAGE =    10.530
                 CONSTANT HEAD =   0.48096                CONSTANT HEAD =   0.00000
                         WELLS =   0.00000                        WELLS =   0.00000
                        DRAINS =   0.00000                       DRAINS =   0.00000
                      RECHARGE =   0.00000                     RECHARGE =   0.00000
                            ET =    443.89                           ET =    12.842
                     TOTAL OUT =    868.39                    TOTAL OUT =    23.372
                      IN - OUT =   0.87115                     IN - OUT =   0.37003E-01
           PERCENT DISCREPANCY =      0.10          PERCENT DISCREPANCY =      0.16


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 37
-----------------------------------------------------------------------------

                  CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                  ------------------                     ------------------------

                     IN:                                      IN:
                     ---                                      ---
                       STORAGE =    62.716                      STORAGE =    1.4340
                 CONSTANT HEAD =    37.998                CONSTANT HEAD =   0.55505
                         WELLS =   0.00000                        WELLS =   0.00000
                        DRAINS =   0.00000                       DRAINS =   0.00000
                      RECHARGE =    791.94                     RECHARGE =    21.404
                            ET =   0.00000                           ET =   0.00000
0                     TOTAL IN =    892.65                     TOTAL IN =    23.393
0                   OUT:                                     OUT:
                    ----                                     ----
                       STORAGE =    434.53                      STORAGE =    10.495
                 CONSTANT HEAD =   0.48096                CONSTANT HEAD =   0.00000
                         WELLS =   0.00000                        WELLS =   0.00000
                        DRAINS =   0.00000                       DRAINS =   0.00000
                      RECHARGE =   0.00000                     RECHARGE =   0.00000
                            ET =    456.75                           ET =    12.869
0                    TOTAL OUT =    891.76                    TOTAL OUT =    23.364
0                     IN - OUT =   0.89740                     IN - OUT =   0.28442E-01
0          PERCENT DISCREPANCY =      0.10          PERCENT DISCREPANCY =       0.12
```

```
VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 38
-----------------------------------------------------------------------------
                    CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                    ------------------                     ------------------------

                          IN:                                       IN:
                          ---                                       ---
                            STORAGE =    64.156                       STORAGE =    1.4316
                      CONSTANT HEAD =    38.518                 CONSTANT HEAD =   0.52293
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =    813.34                      RECHARGE =    21.404
                                 ET =   0.00000                            ET =   0.00000
                           TOTAL IN =    916.02                      TOTAL IN =    23.358

                         OUT:                                      OUT:
                         ----                                      ----
                            STORAGE =    444.97                       STORAGE =    10.429
                      CONSTANT HEAD =   0.48096                 CONSTANT HEAD =   0.00000
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =   0.00000                      RECHARGE =   0.00000
                                 ET =    469.64                            ET =    12.896
0                         TOTAL OUT =    915.09                     TOTAL OUT =    23.325
0                          IN - OUT =   0.92688                      IN - OUT =   0.33457E-01
0               PERCENT DISCREPANCY =      0.10           PERCENT DISCREPANCY =      0.14


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 39
-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                    ------------------                     ------------------------

                          IN:                                       IN:
                          ---                                       ---
                            STORAGE =    65.593                       STORAGE =    1.4287
                      CONSTANT HEAD =    39.002                 CONSTANT HEAD =   0.48817
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =    834.75                      RECHARGE =    21.404
                                 ET =   0.00000                            ET =   0.00000
0                          TOTAL IN =    939.34                      TOTAL IN =    23.321

0                        OUT:                                      OUT:
                         ----                                      ----
                            STORAGE =    455.36                       STORAGE =    10.370
                      CONSTANT HEAD =   0.48096                 CONSTANT HEAD =   0.00000
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =   0.00000                      RECHARGE =   0.00000
                                 ET =    482.55                            ET =    12.922
0                         TOTAL OUT =    938.39                     TOTAL OUT =    23.292
0                          IN - OUT =   0.95422                      IN - OUT =   0.28557E-01
0               PERCENT DISCREPANCY =      0.10           PERCENT DISCREPANCY =      0.12

0

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 40
-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                    ------------------                     ------------------------

                          IN:                                       IN:
                          ---                                       ---
                            STORAGE =    67.018                       STORAGE =    1.4196
                      CONSTANT HEAD =    39.412                 CONSTANT HEAD =   0.34378
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =    856.15                      RECHARGE =    21.404
                                 ET =   0.00000                            ET =   0.00000
0                          TOTAL IN =    962.58                      TOTAL IN =    23.167
```

```
0                        OUT:                                      OUT:
                         ----                                      ----
                            STORAGE =    465.63                       STORAGE =    10.188
                      CONSTANT HEAD =   0.48096                 CONSTANT HEAD =   0.00000
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =   0.00000                      RECHARGE =   0.00000
                                 ET =    495.49                            ET =    12.948
0                         TOTAL OUT =    961.60                     TOTAL OUT =    23.135
0                          IN - OUT =   0.98462                      IN - OUT =   0.31782E-01
0               PERCENT DISCREPANCY =      0.10           PERCENT DISCREPANCY =      0.14


                              VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS
PERIOD 41

-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3          RATES FOR THIS TIME STEP      L**3/T
                    ------------------                    ------------------------

                          IN:                                       IN:
                          ---                                       ---
                            STORAGE =    68.450                       STORAGE =    1.4142
                      CONSTANT HEAD =    39.631                 CONSTANT HEAD =   0.22940
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =    877.56                      RECHARGE =    21.404
                                 ET =   0.00000                            ET =   0.00000
0                          TOTAL IN =    985.64                      TOTAL IN =    23.047
0                        OUT:                                      OUT:
                         ----                                      ----
                            STORAGE =    475.69                       STORAGE =    10.044
                      CONSTANT HEAD =   0.48096                 CONSTANT HEAD =   0.00000
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =   0.00000                      RECHARGE =   0.00000
                                 ET =    508.45                            ET =    12.973
0                         TOTAL OUT =    984.62                     TOTAL OUT =    23.018
0                          IN - OUT =    1.0123                      IN - OUT =   0.29793E-01
0               PERCENT DISCREPANCY =      0.10           PERCENT DISCREPANCY =      0.13


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 42
-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3          RATES FOR THIS TIME STEP      L**3/T
                    ------------------                    ------------------------

                          IN:                                       IN:
                          ---                                       ---
                            STORAGE =    69.932                       STORAGE =    1.4391
                      CONSTANT HEAD =    39.752                 CONSTANT HEAD =   0.15447
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =    898.96                      RECHARGE =    21.404
                                 ET =   0.00000                            ET =   0.00000
0                          TOTAL IN =    1008.6                      TOTAL IN =    22.997

0                        OUT:                                      OUT:
                         ----                                      ----
                            STORAGE =    485.67                       STORAGE =    9.9669
                      CONSTANT HEAD =   0.48096                 CONSTANT HEAD =   0.00000
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =   0.00000                      RECHARGE =   0.00000
                                 ET =    521.44                            ET =    12.999
0                         TOTAL OUT =    1007.6                     TOTAL OUT =    22.966
0                          IN - OUT =    1.0460                      IN - OUT =   0.31542E-01
0               PERCENT DISCREPANCY =      0.10           PERCENT DISCREPANCY =      0.14


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 43
-----------------------------------------------------------------------------
```

```
0                   CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                    ------------------                     ------------------------

                          IN:                                       IN:
                          ---                                       ---
                            STORAGE =    71.411                       STORAGE =    1.4314
                      CONSTANT HEAD =    39.823                 CONSTANT HEAD =   0.10275
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =    920.36                      RECHARGE =    21.404
                                 ET =   0.00000                            ET =   0.00000
0                          TOTAL IN =    1031.6                      TOTAL IN =    22.938
0                        OUT:                                      OUT:
                         ----                                      ----
                            STORAGE =    495.58                       STORAGE =    9.8851
                      CONSTANT HEAD =   0.48252                 CONSTANT HEAD =   0.00000
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =   0.00000                      RECHARGE =   0.00000
                                 ET =    534.46                            ET =    13.024
0                         TOTAL OUT =    1030.5                     TOTAL OUT =    22.909
0                          IN - OUT =    1.0732                      IN - OUT =   0.28553E-01
0               PERCENT DISCREPANCY =      0.10           PERCENT DISCREPANCY =      0.12


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 44
-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                    ------------------                     ------------------------

                          IN:                                       IN:
                          ---                                       ---
                            STORAGE =    72.989                       STORAGE =    1.5541
                      CONSTANT HEAD =    39.823                 CONSTANT HEAD =   0.00000
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =    941.77                      RECHARGE =    21.404
                                 ET =   0.00000                            ET =   0.00000
0                          TOTAL IN =    1054.6                      TOTAL IN =    22.958

0                        OUT:                                      OUT:
                         ----                                      ----
                            STORAGE =    505.42                       STORAGE =    9.8276
                      CONSTANT HEAD =   0.55811                 CONSTANT HEAD =   0.61268E-01
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =   0.00000                      RECHARGE =   0.00000
                                 ET =    547.50                            ET =    13.049
0                         TOTAL OUT =    1053.5                     TOTAL OUT =    22.938
0                          IN - OUT =    1.0996                      IN - OUT =   0.19571E-01
0               PERCENT DISCREPANCY =      0.10           PERCENT DISCREPANCY =      0.09


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 45
-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                    ------------------                     ------------------------

                          IN:                                       IN:
                          ---                                       ---
                            STORAGE =    74.899                       STORAGE =    1.8925
                      CONSTANT HEAD =    39.823                 CONSTANT HEAD =   0.00000
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =    963.17                      RECHARGE =    21.404
                                 ET =   0.00000                            ET =   0.00000
0                          TOTAL IN =    1077.9                      TOTAL IN =    23.296

0                        OUT:                                      OUT:
                         ----                                      ----
                            STORAGE =    515.21                       STORAGE =    9.7923
                      CONSTANT HEAD =   0.98269                 CONSTANT HEAD =   0.40513
```

```
                          WELLS =   0.00000                          WELLS =   0.00000
                         DRAINS =   0.00000                         DRAINS =   0.00000
                       RECHARGE =   0.00000                       RECHARGE =   0.00000
                             ET =    560.57                             ET =    13.074
0                     TOTAL OUT =    1076.8                      TOTAL OUT =    23.272
0                      IN - OUT =    1.1268                       IN - OUT =   0.24458E-01
0          PERCENT DISCREPANCY =      0.10          PERCENT DISCREPANCY =      0.11


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 46
-----------------------------------------------------------------------------
0                 CUMULATIVE VOLUMES      L**3         RATES FOR THIS TIME STEP      L**3/T
                  ------------------                   ------------------------

                        IN:                                      IN:
                        ---                                      ---
                        STORAGE =    77.113                        STORAGE =    2.1841
                  CONSTANT HEAD =    39.823                  CONSTANT HEAD =   0.00000
                          WELLS =   0.00000                          WELLS =   0.00000
                         DRAINS =   0.00000                         DRAINS =   0.00000
                       RECHARGE =    984.57                       RECHARGE =    21.404
                             ET =   0.00000                             ET =   0.00000
0                      TOTAL IN =    1101.5                       TOTAL IN =    23.588

0                      OUT:                                     OUT:
                       ----                                     ----
                        STORAGE =    524.98                        STORAGE =    9.7539
                  CONSTANT HEAD =    1.7219                  CONSTANT HEAD =   0.71374
                          WELLS =   0.00000                          WELLS =   0.00000
                         DRAINS =   0.00000                         DRAINS =   0.00000
                       RECHARGE =   0.00000                       RECHARGE =   0.00000
                             ET =    573.66                             ET =    13.099
0                     TOTAL OUT =    1100.4                      TOTAL OUT =    23.566
0                      IN - OUT =    1.1501                       IN - OUT =   0.21528E-01
0          PERCENT DISCREPANCY =      0.10          PERCENT DISCREPANCY =      0.09


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 47
-----------------------------------------------------------------------------
0                 CUMULATIVE VOLUMES      L**3         RATES FOR THIS TIME STEP      L**3/T
                  ------------------                   ------------------------

                        IN:                                      IN:
                        ---                                      ---
                        STORAGE =    79.542                        STORAGE =    2.3989
                  CONSTANT HEAD =    39.823                  CONSTANT HEAD =   0.00000
                          WELLS =   0.00000                          WELLS =   0.00000
                         DRAINS =   0.00000                         DRAINS =   0.00000
                       RECHARGE =    1006.0                       RECHARGE =    21.404
                             ET =   0.00000                             ET =   0.00000
0                      TOTAL IN =    1125.3                       TOTAL IN =    23.803

0                      OUT:                                     OUT:
                       ----                                     ----
                        STORAGE =    534.71                        STORAGE =    9.7183
                  CONSTANT HEAD =    2.6827                  CONSTANT HEAD =   0.93343
                          WELLS =   0.00000                          WELLS =   0.00000
                         DRAINS =   0.00000                         DRAINS =   0.00000
                       RECHARGE =   0.00000                       RECHARGE =   0.00000
                             ET =    586.77                             ET =    13.123
0                     TOTAL OUT =    1124.2                      TOTAL OUT =    23.774
0                      IN - OUT =    1.1781                       IN - OUT =   0.28292E-01
0          PERCENT DISCREPANCY =      0.10          PERCENT DISCREPANCY =      0.12


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 48
-----------------------------------------------------------------------------
0                 CUMULATIVE VOLUMES      L**3         RATES FOR THIS TIME STEP      L**3/T
                  ------------------                   ------------------------

                        IN:                                      IN:
```

```
                   ---                                        ---
                     STORAGE =    82.015                        STORAGE =    2.4477
               CONSTANT HEAD =    39.823                  CONSTANT HEAD =   0.00000
                       WELLS =   0.00000                          WELLS =   0.00000
                      DRAINS =   0.00000                         DRAINS =   0.00000
                    RECHARGE =    1027.4                       RECHARGE =    21.404
                          ET =   0.00000                             ET =   0.00000
0                   TOTAL IN =    1149.2                       TOTAL IN =    23.851

0                 OUT:                                       OUT:
                  ----                                       ----
                     STORAGE =    544.41                        STORAGE =    9.6886
               CONSTANT HEAD =    3.6924                  CONSTANT HEAD =   0.98674
                       WELLS =   0.00000                          WELLS =   0.00000
                      DRAINS =   0.00000                         DRAINS =   0.00000
                    RECHARGE =   0.00000                       RECHARGE =   0.00000
                          ET =    599.91                             ET =    13.146
0                  TOTAL OUT =    1148.0                      TOTAL OUT =    23.822
0                   IN - OUT =    1.2084                       IN - OUT =   0.29711E-01
0       PERCENT DISCREPANCY =       0.11         PERCENT DISCREPANCY =       0.12


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 49
----------------------------------------------------------------------------
0                  CUMULATIVE VOLUMES      L**3          RATES FOR THIS TIME STEP      L**3/T
                   ------------------                    ------------------------

                   IN:                                        IN:
                   ---                                        ---
                     STORAGE =    84.498                        STORAGE =    2.4617
               CONSTANT HEAD =    39.823                  CONSTANT HEAD =   0.00000
                       WELLS =   0.00000                          WELLS =   0.00000
                      DRAINS =   0.00000                         DRAINS =   0.00000
                    RECHARGE =    1048.8                       RECHARGE =    21.404
                          ET =   0.00000                             ET =   0.00000
0                   TOTAL IN =    1173.1                       TOTAL IN =    23.865

0                 OUT:                                       OUT:
                  ----                                       ----
                     STORAGE =    554.08                        STORAGE =    9.6554
               CONSTANT HEAD =    4.7195                  CONSTANT HEAD =    1.0059
                       WELLS =   0.00000                          WELLS =   0.00000
                      DRAINS =   0.00000                         DRAINS =   0.00000
                    RECHARGE =   0.00000                       RECHARGE =   0.00000
                          ET =    613.07                             ET =    13.170
0                  TOTAL OUT =    1171.9                      TOTAL OUT =    23.831
0                   IN - OUT =    1.2350                       IN - OUT =   0.34164E-01
0       PERCENT DISCREPANCY =       0.11         PERCENT DISCREPANCY =       0.14


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 50
----------------------------------------------------------------------------
0                  CUMULATIVE VOLUMES      L**3          RATES FOR THIS TIME STEP      L**3/T
                   ------------------                    ------------------------

                   IN:                                        IN:
                   ---                                        ---
                     STORAGE =    86.934                        STORAGE =    2.4149
               CONSTANT HEAD =    39.823                  CONSTANT HEAD =   0.00000
                       WELLS =   0.00000                          WELLS =   0.00000
                      DRAINS =   0.00000                         DRAINS =   0.00000
                    RECHARGE =    1070.2                       RECHARGE =    21.404
                          ET =   0.00000                             ET =   0.00000
0                   TOTAL IN =    1196.9                       TOTAL IN =    23.819

0                 OUT:                                       OUT:
                  ----                                       ----
                     STORAGE =    563.72                        STORAGE =    9.6299
               CONSTANT HEAD =    5.7053                  CONSTANT HEAD =   0.96826
                       WELLS =   0.00000                          WELLS =   0.00000
                      DRAINS =   0.00000                         DRAINS =   0.00000
                    RECHARGE =   0.00000                       RECHARGE =   0.00000
```

```
                        ET =    626.26                         ET =    13.193
0                TOTAL OUT =    1195.7                  TOTAL OUT =    23.791
0                 IN - OUT =    1.2631                   IN - OUT =  0.27250E-01
0     PERCENT DISCREPANCY =       0.11       PERCENT DISCREPANCY =       0.11


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 51
-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3          RATES FOR THIS TIME STEP      L**3/T
                    ------------------                    ------------------------

                         IN:                                       IN:
                         ---                                       ---
                   STORAGE =    89.338                       STORAGE =    2.3841
             CONSTANT HEAD =    39.823                 CONSTANT HEAD =  0.00000
                     WELLS =  0.00000                          WELLS =  0.00000
                    DRAINS =  0.00000                         DRAINS =  0.00000
                  RECHARGE =    1091.6                      RECHARGE =    21.404
                        ET =  0.00000                             ET =  0.00000
0                 TOTAL IN =    1220.8                      TOTAL IN =    23.788

0                       OUT:                                      OUT:
                        ----                                      ----
                   STORAGE =    573.33                       STORAGE =    9.6000
             CONSTANT HEAD =    6.6661                 CONSTANT HEAD =  0.94442
                     WELLS =  0.00000                          WELLS =  0.00000
                    DRAINS =  0.00000                         DRAINS =  0.00000
                  RECHARGE =  0.00000                       RECHARGE =  0.00000
                        ET =    639.47                            ET =    13.216
0                TOTAL OUT =    1219.5                     TOTAL OUT =    23.760
0                 IN - OUT =    1.2942                      IN - OUT =  0.27674E-01
0     PERCENT DISCREPANCY =       0.11       PERCENT DISCREPANCY =       0.12


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 52
-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3          RATES FOR THIS TIME STEP      L**3/T
                    ------------------                    ------------------------

                         IN:                                       IN:
                         ---                                       ---
                   STORAGE =    91.695                       STORAGE =    2.3399
             CONSTANT HEAD =    39.823                 CONSTANT HEAD =  0.00000
                     WELLS =  0.00000                          WELLS =  0.00000
                    DRAINS =  0.00000                         DRAINS =  0.00000
                  RECHARGE =    1113.0                      RECHARGE =    21.404
                        ET =  0.00000                             ET =  0.00000
0                 TOTAL IN =    1244.5                      TOTAL IN =    23.744

0                       OUT:                                      OUT:
                        ----                                      ----
                   STORAGE =    582.91                       STORAGE =    9.5638
             CONSTANT HEAD =    7.5926                 CONSTANT HEAD =  0.91190
                     WELLS =  0.00000                          WELLS =  0.00000
                    DRAINS =  0.00000                         DRAINS =  0.00000
                  RECHARGE =  0.00000                       RECHARGE =  0.00000
                        ET =    652.70                            ET =    13.239
0                TOTAL OUT =    1243.2                     TOTAL OUT =    23.715
0                 IN - OUT =    1.3164                      IN - OUT =  0.28679E-01
0     PERCENT DISCREPANCY =       0.11       PERCENT DISCREPANCY =       0.12


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 53
-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3          RATES FOR THIS TIME STEP      L**3/T
                    ------------------                    ------------------------

                         IN:                                       IN:
                         ---                                       ---
                   STORAGE =    94.020                       STORAGE =    2.3046
             CONSTANT HEAD =    39.823                 CONSTANT HEAD =  0.00000
```

```
                         WELLS =   0.00000                       WELLS =   0.00000
                        DRAINS =   0.00000                      DRAINS =   0.00000
                      RECHARGE =    1134.4                    RECHARGE =    21.404
                            ET =   0.00000                          ET =   0.00000
0                     TOTAL IN =    1268.2                    TOTAL IN =    23.708

0                   OUT:                                  OUT:
                    ----                                  ----
                       STORAGE =    592.46                     STORAGE =    9.5470
                 CONSTANT HEAD =    8.4899               CONSTANT HEAD =   0.88376
                         WELLS =   0.00000                       WELLS =   0.00000
                        DRAINS =   0.00000                      DRAINS =   0.00000
                      RECHARGE =   0.00000                    RECHARGE =   0.00000
                            ET =    665.95                          ET =    13.263
0                    TOTAL OUT =    1266.9                   TOTAL OUT =    23.693
0                     IN - OUT =    1.3438                    IN - OUT =   0.15081E-01
0          PERCENT DISCREPANCY =      0.11         PERCENT DISCREPANCY =      0.06


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 54
-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                    ------------------                     ------------------------

                     IN:                                   IN:
                     ---                                   ---
                       STORAGE =    96.310                     STORAGE =    2.2749
                 CONSTANT HEAD =    39.823               CONSTANT HEAD =   0.00000
                         WELLS =   0.00000                       WELLS =   0.00000
                        DRAINS =   0.00000                      DRAINS =   0.00000
                      RECHARGE =    1155.8                    RECHARGE =    21.404
                            ET =   0.00000                          ET =   0.00000
0                     TOTAL IN =    1291.9                    TOTAL IN =    23.679

0                   OUT:                                  OUT:
                    ----                                  ----
                       STORAGE =    601.97                     STORAGE =    9.5060
                 CONSTANT HEAD =    9.3612               CONSTANT HEAD =   0.85880
                         WELLS =   0.00000                       WELLS =   0.00000
                        DRAINS =   0.00000                      DRAINS =   0.00000
                      RECHARGE =   0.00000                    RECHARGE =   0.00000
                            ET =    679.23                          ET =    13.286
0                    TOTAL OUT =    1290.6                   TOTAL OUT =    23.650
0                     IN - OUT =    1.3712                    IN - OUT =   0.28208E-01
0          PERCENT DISCREPANCY =      0.11         PERCENT DISCREPANCY =       0.12


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 55
-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                    ------------------                     ------------------------

                     IN:                                   IN:
                     ---                                   ---
                       STORAGE =    98.571                     STORAGE =    2.2484
                 CONSTANT HEAD =    39.823               CONSTANT HEAD =   0.00000
                         WELLS =   0.00000                       WELLS =   0.00000
                        DRAINS =   0.00000                      DRAINS =   0.00000
                      RECHARGE =    1177.2                    RECHARGE =    21.404
                            ET =   0.00000                          ET =   0.00000
0                     TOTAL IN =    1315.6                    TOTAL IN =    23.652

0                   OUT:                                  OUT:
                    ----                                  ----
                       STORAGE =    611.46                     STORAGE =    9.4706
                 CONSTANT HEAD =    10.209               CONSTANT HEAD =   0.83584
                         WELLS =   0.00000                       WELLS =   0.00000
                        DRAINS =   0.00000                      DRAINS =   0.00000
                      RECHARGE =   0.00000                    RECHARGE =   0.00000
                            ET =    692.53                          ET =    13.308
0                    TOTAL OUT =    1314.2                   TOTAL OUT =    23.615
0                     IN - OUT =    1.4033                    IN - OUT =   0.37376E-01
```

```
0              PERCENT DISCREPANCY =      0.11          PERCENT DISCREPANCY =      0.16


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 56
-----------------------------------------------------------------------------
0                  CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                   ------------------                     ------------------------

                         IN:                                       IN:
                         ---                                       ---
                           STORAGE =    100.80                       STORAGE =    2.2165
                     CONSTANT HEAD =    39.823                 CONSTANT HEAD =   0.00000
                             WELLS =   0.00000                         WELLS =   0.00000
                            DRAINS =   0.00000                        DRAINS =   0.00000
                          RECHARGE =    1198.6                      RECHARGE =    21.404
                                ET =   0.00000                            ET =   0.00000
0                         TOTAL IN =    1339.2                      TOTAL IN =    23.620

0                       OUT:                                      OUT:
                        ----                                      ----
                           STORAGE =    620.91                       STORAGE =    9.4429
                     CONSTANT HEAD =    11.035                 CONSTANT HEAD =   0.81599
                             WELLS =   0.00000                         WELLS =   0.00000
                            DRAINS =   0.00000                        DRAINS =   0.00000
                          RECHARGE =   0.00000                      RECHARGE =   0.00000
                                ET =    705.86                            ET =    13.331
0                        TOTAL OUT =    1337.8                     TOTAL OUT =    23.590
0                         IN - OUT =    1.4336                      IN - OUT =   0.30777E-01
0              PERCENT DISCREPANCY =      0.11          PERCENT DISCREPANCY =       0.13


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 57
-----------------------------------------------------------------------------
0                  CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                   ------------------                     ------------------------

                         IN:                                       IN:
                         ---                                       ---
                           STORAGE =    103.01                       STORAGE =    2.1923
                     CONSTANT HEAD =    39.823                 CONSTANT HEAD =   0.00000
                             WELLS =   0.00000                         WELLS =   0.00000
                            DRAINS =   0.00000                        DRAINS =   0.00000
                          RECHARGE =    1220.0                      RECHARGE =    21.404
                                ET =   0.00000                            ET =   0.00000
0                         TOTAL IN =    1362.8                      TOTAL IN =    23.596

0                       OUT:                                      OUT:
                        ----                                      ----
                           STORAGE =    630.34                       STORAGE =    9.4196
                     CONSTANT HEAD =    11.844                 CONSTANT HEAD =   0.79813
                             WELLS =   0.00000                         WELLS =   0.00000
                            DRAINS =   0.00000                        DRAINS =   0.00000
                          RECHARGE =   0.00000                      RECHARGE =   0.00000
                                ET =    719.20                            ET =    13.353
0                        TOTAL OUT =    1361.4                     TOTAL OUT =    23.570
0                         IN - OUT =    1.4622                      IN - OUT =   0.25703E-01
0              PERCENT DISCREPANCY =      0.11          PERCENT DISCREPANCY =      0.11


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 58
-----------------------------------------------------------------------------
0                  CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                   ------------------                     ------------------------

                         IN:                                       IN:
                         ---                                       ---
                           STORAGE =    105.19                       STORAGE =    2.1736
                     CONSTANT HEAD =    39.823                 CONSTANT HEAD =   0.00000
                             WELLS =   0.00000                         WELLS =   0.00000
                            DRAINS =   0.00000                        DRAINS =   0.00000
                          RECHARGE =    1241.4                      RECHARGE =    21.404
```

```
                         ET =   0.00000                            ET =   0.00000
0                  TOTAL IN =    1386.4                      TOTAL IN =    23.577

0                 OUT:                                       OUT:
                  ----                                       ----
                    STORAGE =    639.73                       STORAGE =    9.3765
              CONSTANT HEAD =    12.635                 CONSTANT HEAD =   0.78205
                      WELLS =   0.00000                         WELLS =   0.00000
                     DRAINS =   0.00000                        DRAINS =   0.00000
                   RECHARGE =   0.00000                      RECHARGE =   0.00000
                         ET =    732.57                            ET =    13.375
0                 TOTAL OUT =    1384.9                     TOTAL OUT =    23.534
0                  IN - OUT =    1.4973                      IN - OUT =   0.43692E-01
0       PERCENT DISCREPANCY =      0.11           PERCENT DISCREPANCY =      0.19


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 59
-----------------------------------------------------------------------------
0                 CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                  ------------------                     ------------------------

                        IN:                                        IN:
                        ---                                        ---
                    STORAGE =    107.35                       STORAGE =    2.1449
              CONSTANT HEAD =    39.823                 CONSTANT HEAD =   0.00000
                      WELLS =   0.00000                         WELLS =   0.00000
                     DRAINS =   0.00000                        DRAINS =   0.00000
                   RECHARGE =    1262.8                      RECHARGE =    21.404
                         ET =   0.00000                            ET =   0.00000
0                  TOTAL IN =    1410.0                      TOTAL IN =    23.549

0                 OUT:                                       OUT:
                  ----                                       ----
                    STORAGE =    649.09                       STORAGE =    9.3499
              CONSTANT HEAD =    13.411                 CONSTANT HEAD =   0.76684
                      WELLS =   0.00000                         WELLS =   0.00000
                     DRAINS =   0.00000                        DRAINS =   0.00000
                   RECHARGE =   0.00000                      RECHARGE =   0.00000
                         ET =    745.96                            ET =    13.398
0                 TOTAL OUT =    1408.5                     TOTAL OUT =    23.515
0                  IN - OUT =    1.5295                      IN - OUT =   0.33730E-01
0       PERCENT DISCREPANCY =      0.11           PERCENT DISCREPANCY =      0.14


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 60
-----------------------------------------------------------------------------
0                 CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                  ------------------                     ------------------------

                        IN:                                        IN:
                        ---                                        ---
                    STORAGE =    109.47                       STORAGE =    2.1162
              CONSTANT HEAD =    39.823                 CONSTANT HEAD =   0.00000
                      WELLS =   0.00000                         WELLS =   0.00000
                     DRAINS =   0.00000                        DRAINS =   0.00000
                   RECHARGE =    1284.2                      RECHARGE =    21.404
                         ET =   0.00000                            ET =   0.00000
0                  TOTAL IN =    1433.5                      TOTAL IN =    23.520

0                 OUT:                                       OUT:
                  ----                                       ----
                    STORAGE =    658.43                       STORAGE =    9.3245
              CONSTANT HEAD =    14.166                 CONSTANT HEAD =   0.74633
                      WELLS =   0.00000                         WELLS =   0.00000
                     DRAINS =   0.00000                        DRAINS =   0.00000
                   RECHARGE =   0.00000                      RECHARGE =   0.00000
                         ET =    759.37                            ET =    13.421
0                 TOTAL OUT =    1432.0                     TOTAL OUT =    23.492
0                  IN - OUT =    1.5577                      IN - OUT =   0.27994E-01
0       PERCENT DISCREPANCY =      0.11           PERCENT DISCREPANCY =      0.12
```

```
VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 61
-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3          RATES FOR THIS TIME STEP      L**3/T
                    ------------------                    ------------------------

                          IN:                                       IN:
                          ---                                       ---
                            STORAGE =    111.57                       STORAGE =    2.0879
                      CONSTANT HEAD =    39.823                 CONSTANT HEAD =   0.00000
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =    1305.6                      RECHARGE =    21.404
                                 ET =   0.00000                            ET =   0.00000
0                          TOTAL IN =    1457.0                      TOTAL IN =    23.492

0                        OUT:                                      OUT:
                         ----                                      ----
                            STORAGE =    667.74                       STORAGE =    9.3001
                      CONSTANT HEAD =    14.901                 CONSTANT HEAD =   0.72745
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =   0.00000                      RECHARGE =   0.00000
                                 ET =    772.81                            ET =    13.444
0                         TOTAL OUT =    1455.4                     TOTAL OUT =    23.471
0                          IN - OUT =    1.5818                      IN - OUT =   0.20605E-01
0               PERCENT DISCREPANCY =      0.11           PERCENT DISCREPANCY =      0.09


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 62
 -----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3          RATES FOR THIS TIME STEP      L**3/T
                    ------------------                    ------------------------

                          IN:                                       IN:
                          ---                                       ---
                            STORAGE =    113.65                       STORAGE =    2.0622
                      CONSTANT HEAD =    39.823                 CONSTANT HEAD =   0.00000
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =    1327.0                      RECHARGE =    21.404
                                 ET =   0.00000                            ET =   0.00000
0                          TOTAL IN =    1480.5                      TOTAL IN =    23.466

0                        OUT:                                      OUT:
                         ----                                      ----
                            STORAGE =    677.01                       STORAGE =    9.2637
                      CONSTANT HEAD =    15.618                 CONSTANT HEAD =   0.70999
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =   0.00000                      RECHARGE =   0.00000
                                 ET =    786.27                            ET =    13.466
0                         TOTAL OUT =    1478.9                     TOTAL OUT =    23.439
0                          IN - OUT =    1.6118                      IN - OUT =   0.26604E-01
0               PERCENT DISCREPANCY =      0.11           PERCENT DISCREPANCY =      0.11


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 63
-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3          RATES FOR THIS TIME STEP      L**3/T
                    ------------------                    ------------------------

                          IN:                                       IN:
                          ---                                       ---
                            STORAGE =    115.70                       STORAGE =    2.0434
                      CONSTANT HEAD =    39.823                 CONSTANT HEAD =   0.00000
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =    1348.4                      RECHARGE =    21.404
                                 ET =   0.00000                            ET =   0.00000
0                          TOTAL IN =    1504.0                      TOTAL IN =    23.447

0                        OUT:                                      OUT:
```

```
                     ----                                    ----
                        STORAGE =    686.25                     STORAGE =    9.2339
                  CONSTANT HEAD =    16.319               CONSTANT HEAD =   0.69382
                          WELLS =   0.00000                       WELLS =   0.00000
                         DRAINS =   0.00000                      DRAINS =   0.00000
                       RECHARGE =   0.00000                    RECHARGE =   0.00000
                             ET =    799.75                          ET =    13.488
0                     TOTAL OUT =    1502.3                   TOTAL OUT =    23.415
0                      IN - OUT =    1.6406                    IN - OUT =   0.31948E-01
0          PERCENT DISCREPANCY =       0.11         PERCENT DISCREPANCY =      0.14


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 64
-----------------------------------------------------------------------------
0                  CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                   ------------------                     ------------------------

                      IN:                                     IN:
                      ---                                     ---
                        STORAGE =    117.73                     STORAGE =    2.0225
                  CONSTANT HEAD =    39.823               CONSTANT HEAD =   0.00000
                          WELLS =   0.00000                       WELLS =   0.00000
                         DRAINS =   0.00000                      DRAINS =   0.00000
                       RECHARGE =    1369.8                    RECHARGE =    21.404
                             ET =   0.00000                          ET =   0.00000
0                      TOTAL IN =    1527.4                    TOTAL IN =    23.426
0                    OUT:                                    OUT:
                     ----                                    ----
                        STORAGE =    695.46                     STORAGE =    9.1874
                  CONSTANT HEAD =    17.004               CONSTANT HEAD =   0.67881
                          WELLS =   0.00000                       WELLS =   0.00000
                         DRAINS =   0.00000                      DRAINS =   0.00000
                       RECHARGE =   0.00000                    RECHARGE =   0.00000
                             ET =    813.25                          ET =    13.509
0                     TOTAL OUT =    1525.7                   TOTAL OUT =    23.376
0                      IN - OUT =    1.6755                    IN - OUT =   0.50682E-01
0          PERCENT DISCREPANCY =       0.11         PERCENT DISCREPANCY =      0.22


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 65
-----------------------------------------------------------------------------
0                  CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                   ------------------                     ------------------------

                      IN:                                     IN:
                      ---                                     ---
                        STORAGE =    119.73                     STORAGE =    1.9915
                  CONSTANT HEAD =    39.823               CONSTANT HEAD =   0.00000
                          WELLS =   0.00000                       WELLS =   0.00000
                         DRAINS =   0.00000                      DRAINS =   0.00000
                       RECHARGE =    1391.2                    RECHARGE =    21.404
                             ET =   0.00000                          ET =   0.00000
0                      TOTAL IN =    1550.8                    TOTAL IN =    23.395

0                    OUT:                                    OUT:
                     ----                                    ----
                        STORAGE =    704.65                     STORAGE =    9.1661
                  CONSTANT HEAD =    17.671               CONSTANT HEAD =   0.66080
                          WELLS =   0.00000                       WELLS =   0.00000
                         DRAINS =   0.00000                      DRAINS =   0.00000
                       RECHARGE =   0.00000                    RECHARGE =   0.00000
                             ET =    826.77                          ET =    13.531
0                     TOTAL OUT =    1549.1                   TOTAL OUT =    23.358
0                      IN - OUT =    1.7042                    IN - OUT =   0.37508E-01
0          PERCENT DISCREPANCY =       0.11         PERCENT DISCREPANCY =      0.16


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 66
-----------------------------------------------------------------------------
0                  CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                   ------------------                     ------------------------
```

```
                     IN:                                      IN:
                     ---                                      ---
                       STORAGE =    121.71                      STORAGE =    1.9750
                 CONSTANT HEAD =    39.823                CONSTANT HEAD =   0.00000
                         WELLS =   0.00000                        WELLS =   0.00000
                        DRAINS =   0.00000                       DRAINS =   0.00000
                      RECHARGE =    1412.7                     RECHARGE =    21.404
                            ET =   0.00000                           ET =   0.00000
0                     TOTAL IN =    1574.2                     TOTAL IN =    23.379

0                   OUT:                                     OUT:
                    ----                                     ----
                       STORAGE =    713.82                      STORAGE =    9.1587
                 CONSTANT HEAD =    18.320                CONSTANT HEAD =   0.64392
                         WELLS =   0.00000                        WELLS =   0.00000
                        DRAINS =   0.00000                       DRAINS =   0.00000
                      RECHARGE =   0.00000                     RECHARGE =   0.00000
                            ET =    840.32                           ET =    13.552
0                    TOTAL OUT =    1572.5                    TOTAL OUT =    23.354
0                     IN - OUT =    1.7271                     IN - OUT =   0.24294E-01
0          PERCENT DISCREPANCY =      0.11          PERCENT DISCREPANCY =      0.10


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 67
-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                    ------------------                     ------------------------

                     IN:                                      IN:
                     ---                                      ---
                       STORAGE =    123.66                      STORAGE =    1.9529
                 CONSTANT HEAD =    39.823                CONSTANT HEAD =   0.00000
                         WELLS =   0.00000                        WELLS =   0.00000
                        DRAINS =   0.00000                       DRAINS =   0.00000
                      RECHARGE =    1434.1                     RECHARGE =    21.404
                            ET =   0.00000                           ET =   0.00000
0                     TOTAL IN =    1597.5                     TOTAL IN =    23.357

0                   OUT:                                     OUT:
                    ----                                     ----
                       STORAGE =    722.95                      STORAGE =    9.1288
                 CONSTANT HEAD =    18.953                CONSTANT HEAD =   0.62805
                         WELLS =   0.00000                        WELLS =   0.00000
                        DRAINS =   0.00000                       DRAINS =   0.00000
                      RECHARGE =   0.00000                     RECHARGE =   0.00000
                            ET =    853.88                           ET =    13.573
0                    TOTAL OUT =    1595.8                    TOTAL OUT =    23.329
0                     IN - OUT =    1.7595                     IN - OUT =   0.27399E-01
0          PERCENT DISCREPANCY =      0.11          PERCENT DISCREPANCY =      0.12


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 68
-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                    ------------------                     ------------------------

                     IN:                                      IN:
                     ---                                      ---
                       STORAGE =    125.60                      STORAGE =    1.9242
                 CONSTANT HEAD =    39.823                CONSTANT HEAD =   0.00000
                         WELLS =   0.00000                        WELLS =   0.00000
                        DRAINS =   0.00000                       DRAINS =   0.00000
                      RECHARGE =    1455.5                     RECHARGE =    21.404
                            ET =   0.00000                           ET =   0.00000
0                     TOTAL IN =    1620.9                     TOTAL IN =    23.328

0                   OUT:                                     OUT:
                    ----                                     ----
                       STORAGE =    732.05                      STORAGE =    9.0933
                 CONSTANT HEAD =    19.572                CONSTANT HEAD =   0.61316
                         WELLS =   0.00000                        WELLS =   0.00000
                        DRAINS =   0.00000                       DRAINS =   0.00000
```

```
                  RECHARGE =   0.00000                  RECHARGE =   0.00000
                        ET =    867.47                        ET =    13.593
0                TOTAL OUT =    1619.1                 TOTAL OUT =    23.300
0                 IN - OUT =    1.7882                  IN - OUT =   0.28488E-01
0     PERCENT DISCREPANCY =      0.11       PERCENT DISCREPANCY =      0.12


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 69
-----------------------------------------------------------------------------
0              CUMULATIVE VOLUMES      L**3         RATES FOR THIS TIME STEP      L**3/T
               ------------------                   ------------------------

                     IN:                                      IN:
                     ---                                      ---
                   STORAGE =    127.51                   STORAGE =    1.9000
             CONSTANT HEAD =    39.823             CONSTANT HEAD =   0.00000
                     WELLS =   0.00000                     WELLS =   0.00000
                    DRAINS =   0.00000                    DRAINS =   0.00000
                  RECHARGE =    1476.9                  RECHARGE =    21.404
                        ET =   0.00000                        ET =   0.00000
0                 TOTAL IN =    1644.2                  TOTAL IN =    23.304

0                   OUT:                                     OUT:
                    ----                                     ----
                   STORAGE =    741.12                   STORAGE =    9.0701
             CONSTANT HEAD =    20.175             CONSTANT HEAD =   0.59912
                     WELLS =   0.00000                     WELLS =   0.00000
                    DRAINS =   0.00000                    DRAINS =   0.00000
                  RECHARGE =   0.00000                  RECHARGE =   0.00000
                        ET =    881.08                        ET =    13.613
0                TOTAL OUT =    1642.4                 TOTAL OUT =    23.283
0                 IN - OUT =    1.8177                  IN - OUT =   0.21170E-01
0     PERCENT DISCREPANCY =      0.11       PERCENT DISCREPANCY =      0.09


VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  3 IN STRESS PERIOD 70
-----------------------------------------------------------------------------
0              CUMULATIVE VOLUMES      L**3         RATES FOR THIS TIME STEP      L**3/T
               ------------------                   ------------------------

                     IN:                                      IN:
                     ---                                      ---
                   STORAGE =    129.39                   STORAGE =    1.8801
             CONSTANT HEAD =    39.823             CONSTANT HEAD =   0.00000
                     WELLS =   0.00000                     WELLS =   0.00000
                    DRAINS =   0.00000                    DRAINS =   0.00000
                  RECHARGE =    1498.3                  RECHARGE =    21.404
                        ET =   0.00000                        ET =   0.00000
0                 TOTAL IN =    1667.5                  TOTAL IN =    23.284

0                   OUT:                                     OUT:
                    ----                                     ----
                   STORAGE =    750.17                   STORAGE =    9.0380
             CONSTANT HEAD =    20.765             CONSTANT HEAD =   0.58583
                     WELLS =   0.00000                     WELLS =   0.00000
                    DRAINS =   0.00000                    DRAINS =   0.00000
                  RECHARGE =   0.00000                  RECHARGE =   0.00000
                        ET =    894.70                        ET =    13.634
0                TOTAL OUT =    1665.6                 TOTAL OUT =    23.258
0                 IN - OUT =    1.8452                  IN - OUT =   0.26363E-01
0     PERCENT DISCREPANCY =      0.11       PERCENT DISCREPANCY =      0.11


0


          TIME SUMMARY AT END OF TIME STEP  3 IN STRESS PERIOD 70
                              SECONDS        MINUTES         HOURS          DAYS            YEARS

---------------------------------------------------------------------------
```

```
      TIME STEP LENGTH         28800.0         480.000         8.00000        0.333333
0.912617E-03
    STRESS PERIOD TIME         86400.0         1440.00         24.0000         1.00000
0.273785E-02
 TOTAL SIMULATION TIME        0.604800E+07    100800.         1680.00         70.0000
0.191649
```

Table F-18 Volumetric Budget Output for the Transient Model of a Year with the Devils Lake Outlet at Cross-section 2 (12 stress periods)

```
                              VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 31 IN STRESS
PERIOD  1
-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3          RATES FOR THIS TIME STEP      L**3/T
                    ------------------                    ------------------------

                          IN:                                       IN:
                          ---                                       ---
                            STORAGE =    44.424                       STORAGE =    1.3857
                      CONSTANT HEAD =   0.00000                 CONSTANT HEAD =   0.00000
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =   0.00000                      RECHARGE =   0.00000
                                 ET =   0.00000                            ET =   0.00000
0                          TOTAL IN =    44.424                      TOTAL IN =    1.3857
0                         OUT:                                      OUT:
                          ----                                      ----
                            STORAGE =    3.7128                       STORAGE =   0.11845
                      CONSTANT HEAD =    40.769                 CONSTANT HEAD =    1.2724
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =   0.00000                      RECHARGE =   0.00000
                                 ET =   0.00000                            ET =   0.00000
0                         TOTAL OUT =    44.482                     TOTAL OUT =    1.3909
0                          IN - OUT =  -0.58018E-01                  IN - OUT =  -0.51500E-02
0               PERCENT DISCREPANCY =     -0.13           PERCENT DISCREPANCY =     -0.37


0


          TIME SUMMARY AT END OF TIME STEP 31 IN STRESS PERIOD  1
                               SECONDS        MINUTES         HOURS          DAYS           YEARS
---------------------------------------------------------------------------
      TIME STEP LENGTH         86400.0        1440.00        24.0000        1.00000
0.273785E-02
    STRESS PERIOD TIME        0.267840E+07    44640.0        744.000        31.0000
0.848734E-01
 TOTAL SIMULATION TIME        0.267840E+07    44640.0        744.000        31.0000
0.848734E-01
1
                              VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 28 IN STRESS
PERIOD  2
-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3          RATES FOR THIS TIME STEP      L**3/T
                    ------------------                    ------------------------

                          IN:                                       IN:
                          ---                                       ---
                            STORAGE =    81.431                       STORAGE =    1.2598
                      CONSTANT HEAD =   0.00000                 CONSTANT HEAD =   0.00000
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =   0.00000                      RECHARGE =   0.00000
                                 ET =   0.00000                            ET =   0.00000
0                          TOTAL IN =    81.431                      TOTAL IN =    1.2598
0                         OUT:                                      OUT:
                          ----                                      ----
                            STORAGE =    7.7450                       STORAGE =   0.17311
                      CONSTANT HEAD =    73.796                 CONSTANT HEAD =    1.0898
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =   0.00000                      RECHARGE =   0.00000
```

```
                             ET =   0.00000                                  ET =   0.00000
0                     TOTAL OUT =    81.541                           TOTAL OUT =    1.2629
0                      IN - OUT =  -0.11032                            IN - OUT =  -0.31090E-02
0           PERCENT DISCREPANCY =     -0.14               PERCENT DISCREPANCY =     -0.25



0


          TIME SUMMARY AT END OF TIME STEP 28 IN STRESS PERIOD  2
                               SECONDS        MINUTES         HOURS          DAYS           YEARS

---------------------------------------------------------------------------
      TIME STEP LENGTH         87171.4        1452.86        24.2143        1.00893
0.276230E-02
    STRESS PERIOD TIME        0.244080E+07    40680.0        678.000        28.2500
0.773443E-01
 TOTAL SIMULATION TIME        0.511920E+07    85320.1        1422.00        59.2501
0.162218
1

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 31 IN STRESS PERIOD  3

-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3          RATES FOR THIS TIME STEP      L**3/T
                    ------------------                    ------------------------

                          IN:                                     IN:
                          ---                                     ---
                            STORAGE =    81.431                     STORAGE =   0.00000
                      CONSTANT HEAD =   0.00000               CONSTANT HEAD =   0.00000
                              WELLS =   0.00000                       WELLS =   0.00000
                             DRAINS =   0.00000                      DRAINS =   0.00000
                           RECHARGE =    1049.3                    RECHARGE =    33.847
                                 ET =   0.00000                          ET =   0.00000
0                          TOTAL IN =    1130.7                    TOTAL IN =    33.847
0                        OUT:                                    OUT:
                         ----                                    ----
                            STORAGE =    1016.7                     STORAGE =    32.541
                      CONSTANT HEAD =    113.60               CONSTANT HEAD =    1.2916
                              WELLS =   0.00000                       WELLS =   0.00000
                             DRAINS =   0.00000                      DRAINS =   0.00000
                           RECHARGE =   0.00000                    RECHARGE =   0.00000
                                 ET =   0.00000                          ET =   0.00000
0                         TOTAL OUT =    1130.3                   TOTAL OUT =    33.833
0                          IN - OUT =   0.37549                    IN - OUT =   0.14133E-01
0               PERCENT DISCREPANCY =      0.03         PERCENT DISCREPANCY =      0.04



0


          TIME SUMMARY AT END OF TIME STEP 31 IN STRESS PERIOD  3
                               SECONDS        MINUTES         HOURS          DAYS           YEARS

---------------------------------------------------------------------------
      TIME STEP LENGTH         86400.0        1440.00        24.0000        1.00000
0.273785E-02
    STRESS PERIOD TIME        0.267840E+07    44640.0        744.000        31.0000
0.848734E-01
 TOTAL SIMULATION TIME        0.779760E+07    129960.        2166.00        90.2501
0.247091
1

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 30 IN STRESS PERIOD  4

-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3          RATES FOR THIS TIME STEP      L**3/T
                    ------------------                    ------------------------

                          IN:                                     IN:
                          ---                                     ---
```

```
                    STORAGE =    303.99                  STORAGE =    7.3204
              CONSTANT HEAD =   0.00000            CONSTANT HEAD =   0.00000
                      WELLS =   0.00000                    WELLS =   0.00000
                     DRAINS =   0.00000                   DRAINS =   0.00000
                   RECHARGE =    1776.8                 RECHARGE =    24.250
                         ET =   0.00000                       ET =   0.00000
0                  TOTAL IN =    2080.8                 TOTAL IN =    31.571
0                OUT:                                 OUT:
                 ----                                 ----
                    STORAGE =    1031.9                  STORAGE =   0.29409
              CONSTANT HEAD =    155.45            CONSTANT HEAD =    1.4883
                      WELLS =   0.00000                    WELLS =   0.00000
                     DRAINS =   0.00000                   DRAINS =   0.00000
                   RECHARGE =   0.00000                 RECHARGE =   0.00000
                         ET =    892.97                       ET =    29.785
0                 TOTAL OUT =    2080.3                TOTAL OUT =    31.568
0                  IN - OUT =   0.43555                 IN - OUT =   0.29736E-02
0      PERCENT DISCREPANCY =                0.02 PERCENT DISCREPANCY =
0.01


0


          TIME SUMMARY AT END OF TIME STEP 30 IN STRESS PERIOD  4
                               SECONDS       MINUTES        HOURS          DAYS           YEARS

---------------------------------------------------------------------------
      TIME STEP LENGTH         86400.0       1440.00       24.0000       1.00000
0.273785E-02
    STRESS PERIOD TIME        0.259200E+07   43200.0       720.000       30.0000
0.821355E-01
 TOTAL SIMULATION TIME        0.103896E+08   173160.       2886.00       120.250
0.329227
1

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 31 IN STRESS PERIOD  5

-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3          RATES FOR THIS TIME STEP      L**3/T
                    ------------------                    ------------------------

                          IN:                                      IN:
                          ---                                      ---
                    STORAGE =    341.87                  STORAGE =    1.2275
              CONSTANT HEAD =   0.00000            CONSTANT HEAD =   0.00000
                      WELLS =   0.00000                    WELLS =   0.00000
                     DRAINS =   0.00000                   DRAINS =   0.00000
                   RECHARGE =    2740.2                 RECHARGE =    31.079
                         ET =   0.00000                       ET =   0.00000
0                  TOTAL IN =    3082.1                 TOTAL IN =    32.307
0                OUT:                                 OUT:
                 ----                                 ----
                    STORAGE =    1055.1                  STORAGE =   0.56525
              CONSTANT HEAD =    206.41            CONSTANT HEAD =    1.7258
                      WELLS =   0.00000                    WELLS =   0.00000
                     DRAINS =   0.00000                   DRAINS =   0.00000
                   RECHARGE =   0.00000                 RECHARGE =   0.00000
                         ET =    1820.3                       ET =    30.016
0                 TOTAL OUT =    3081.8                TOTAL OUT =    32.307
0                  IN - OUT =   0.30835                 IN - OUT =   0.24033E-03
0      PERCENT DISCREPANCY =       0.01      PERCENT DISCREPANCY =      0.00


0


          TIME SUMMARY AT END OF TIME STEP 31 IN STRESS PERIOD  5
                               SECONDS       MINUTES        HOURS          DAYS           YEARS

---------------------------------------------------------------------------
```

```
      TIME STEP LENGTH         86400.0        1440.00        24.0000        1.00000
0.273785E-02
    STRESS PERIOD TIME       0.267840E+07    44640.0        744.000        31.0000
0.848734E-01
 TOTAL SIMULATION TIME       0.130680E+08    217800.        3630.00        151.250
0.414100
1

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 30 IN STRESS PERIOD  6

-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                    ------------------                     ------------------------

                          IN:                                        IN:
                          ---                                        ---
                            STORAGE =    341.87                        STORAGE =   0.36713E-03
                      CONSTANT HEAD =   0.00000                  CONSTANT HEAD =   0.00000
                              WELLS =   0.00000                          WELLS =   0.00000
                             DRAINS =   0.00000                         DRAINS =   0.00000
                           RECHARGE =    4156.0                       RECHARGE =    47.191
                                 ET =   0.00000                             ET =   0.00000
0                          TOTAL IN =    4497.8                       TOTAL IN =    47.192
0                        OUT:                                       OUT:
                         ----                                       ----
                            STORAGE =    1504.5                        STORAGE =    14.656
                      CONSTANT HEAD =    262.68                  CONSTANT HEAD =    1.9297
                              WELLS =   0.00000                          WELLS =   0.00000
                             DRAINS =   0.00000                         DRAINS =   0.00000
                           RECHARGE =   0.00000                       RECHARGE =   0.00000
                                 ET =    2730.5                             ET =    30.612
0                         TOTAL OUT =    4497.7                      TOTAL OUT =    47.198
0                          IN - OUT =   0.13721                       IN - OUT =  -0.63362E-02
0               PERCENT DISCREPANCY =      0.00            PERCENT DISCREPANCY =     -0.01


0


          TIME SUMMARY AT END OF TIME STEP 30 IN STRESS PERIOD  6
                               SECONDS        MINUTES         HOURS          DAYS          YEARS

---------------------------------------------------------------------------
      TIME STEP LENGTH         86400.0        1440.00        24.0000        1.00000
0.273785E-02
    STRESS PERIOD TIME       0.259200E+07    43200.0        720.000        30.0000
0.821355E-01
 TOTAL SIMULATION TIME       0.156600E+08    261000.        4350.00        181.250
0.496236
1

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 31 IN STRESS PERIOD  7

-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                    ------------------                     ------------------------

                          IN:                                        IN:
                          ---                                        ---
                            STORAGE =    343.34                        STORAGE =   0.31594E-01
                      CONSTANT HEAD =   0.00000                  CONSTANT HEAD =   0.00000
                              WELLS =   0.00000                          WELLS =   0.00000
                             DRAINS =   0.00000                         DRAINS =   0.00000
                           RECHARGE =    5257.1                       RECHARGE =    35.520
                                 ET =   0.00000                             ET =   0.00000
0                          TOTAL IN =    5600.4                       TOTAL IN =    35.552
0                        OUT:                                       OUT:
                         ----                                       ----
                            STORAGE =    1597.9                        STORAGE =    2.9439
                      CONSTANT HEAD =    320.87                  CONSTANT HEAD =    1.8855
                              WELLS =   0.00000                          WELLS =   0.00000
                             DRAINS =   0.00000                         DRAINS =   0.00000
                           RECHARGE =   0.00000                       RECHARGE =   0.00000
```

```
                        ET =    3681.2                          ET =    30.712
0                TOTAL OUT =    5600.0                   TOTAL OUT =    35.542
0                 IN - OUT =   0.39502                    IN - OUT =   0.10471E-01
0     PERCENT DISCREPANCY =       0.01         PERCENT DISCREPANCY =      0.03


0


          TIME SUMMARY AT END OF TIME STEP 31 IN STRESS PERIOD  7
                               SECONDS        MINUTES        HOURS          DAYS          YEARS

---------------------------------------------------------------------------
      TIME STEP LENGTH         86400.0        1440.00        24.0000        1.00000
0.273785E-02
    STRESS PERIOD TIME        0.267840E+07    44640.0        744.000        31.0000
0.848734E-01
 TOTAL SIMULATION TIME        0.183384E+08    305640.        5094.00        212.250
0.581109
1

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 31 IN STRESS PERIOD  8

-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3          RATES FOR THIS TIME STEP      L**3/T
                    ------------------                    ------------------------

                          IN:                                       IN:
                          ---                                       ---
                    STORAGE =    343.98                     STORAGE =   0.19838E-01
              CONSTANT HEAD =   0.00000               CONSTANT HEAD =   0.00000
                      WELLS =   0.00000                       WELLS =   0.00000
                     DRAINS =   0.00000                      DRAINS =   0.00000
                   RECHARGE =    6377.9                    RECHARGE =    36.155
                         ET =   0.00000                          ET =   0.00000
0                 TOTAL IN =    6721.9                    TOTAL IN =    36.175
0                        OUT:                                      OUT:
                         ----                                      ----
                    STORAGE =    1706.3                     STORAGE =    3.4509
              CONSTANT HEAD =    379.57               CONSTANT HEAD =    1.8995
                      WELLS =   0.00000                       WELLS =   0.00000
                     DRAINS =   0.00000                      DRAINS =   0.00000
                   RECHARGE =   0.00000                    RECHARGE =   0.00000
                         ET =    4634.7                          ET =    30.793
0                TOTAL OUT =    6720.5                   TOTAL OUT =    36.143
0                 IN - OUT =    1.3564                    IN - OUT =   0.31780E-01
0     PERCENT DISCREPANCY =       0.02         PERCENT DISCREPANCY =      0.09


0


          TIME SUMMARY AT END OF TIME STEP 31 IN STRESS PERIOD  8
                               SECONDS        MINUTES        HOURS          DAYS          YEARS

---------------------------------------------------------------------------
      TIME STEP LENGTH         86400.0        1440.00        24.0000        1.00000
0.273785E-02
    STRESS PERIOD TIME        0.267840E+07    44640.0        744.000        31.0000
0.848734E-01
 TOTAL SIMULATION TIME        0.210168E+08    350280.        5838.00        243.250
0.665982
1

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 30 IN STRESS PERIOD  9

-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3          RATES FOR THIS TIME STEP      L**3/T
                    ------------------                    ------------------------

                          IN:                                       IN:
                          ---                                       ---
```

```
                         STORAGE =    705.30                   STORAGE =    11.818
                   CONSTANT HEAD =   0.00000             CONSTANT HEAD =   0.00000
                           WELLS =   0.00000                     WELLS =   0.00000
                          DRAINS =   0.00000                    DRAINS =   0.00000
                        RECHARGE =    6987.5                  RECHARGE =    20.319
                              ET =   0.00000                        ET =   0.00000
0                       TOTAL IN =    7692.8                  TOTAL IN =    32.137
0                     OUT:                                  OUT:
                      ----                                  ----
                         STORAGE =    1706.3                   STORAGE =   0.00000
                   CONSTANT HEAD =    431.89             CONSTANT HEAD =    1.6934
                           WELLS =   0.00000                     WELLS =   0.00000
                          DRAINS =   0.00000                    DRAINS =   0.00000
                        RECHARGE =   0.00000                  RECHARGE =   0.00000
                              ET =    5552.5                        ET =    30.419
0                      TOTAL OUT =    7690.6                 TOTAL OUT =    32.112
0                       IN - OUT =    2.1484                  IN - OUT =   0.24910E-01
0            PERCENT DISCREPANCY =      0.03       PERCENT DISCREPANCY =      0.08


0


          TIME SUMMARY AT END OF TIME STEP 30 IN STRESS PERIOD  9
                               SECONDS        MINUTES         HOURS          DAYS           YEARS

---------------------------------------------------------------------------
      TIME STEP LENGTH         86400.0        1440.00        24.0000        1.00000
0.273785E-02
    STRESS PERIOD TIME        0.259200E+07    43200.0        720.000        30.0000
0.821355E-01
 TOTAL SIMULATION TIME        0.236088E+08    393480.        6558.00        273.250
0.748118
1

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 31 IN STRESS PERIOD 10

-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                    ------------------                     ------------------------

                          IN:                                      IN:
                          ---                                      ---
                         STORAGE =    1237.7                   STORAGE =    16.895
                   CONSTANT HEAD =   0.00000             CONSTANT HEAD =   0.00000
                           WELLS =   0.00000                     WELLS =   0.00000
                          DRAINS =   0.00000                    DRAINS =   0.00000
                        RECHARGE =    7439.7                  RECHARGE =    14.589
                              ET =   0.00000                        ET =   0.00000
0                       TOTAL IN =    8677.4                  TOTAL IN =    31.484
0                     OUT:                                  OUT:
                      ----                                  ----
                         STORAGE =    1706.3                   STORAGE =   0.00000
                   CONSTANT HEAD =    481.53             CONSTANT HEAD =    1.5551
                           WELLS =   0.00000                     WELLS =   0.00000
                          DRAINS =   0.00000                    DRAINS =   0.00000
                        RECHARGE =   0.00000                  RECHARGE =   0.00000
                              ET =    6487.5                        ET =    29.933
0                      TOTAL OUT =    8675.3                 TOTAL OUT =    31.488
0                       IN - OUT =    2.0557                  IN - OUT =  -0.36869E-02
0            PERCENT DISCREPANCY =      0.02       PERCENT DISCREPANCY =     -0.01


0


          TIME SUMMARY AT END OF TIME STEP 31 IN STRESS PERIOD 10
                               SECONDS        MINUTES         HOURS          DAYS           YEARS

---------------------------------------------------------------------------
      TIME STEP LENGTH         86400.0        1440.00        24.0000        1.00000
0.273785E-02
```

```
    STRESS PERIOD TIME        0.267840E+07    44640.0        744.000        31.0000
0.848734E-01
 TOTAL SIMULATION TIME        0.262872E+08    438120.        7302.00        304.250
0.832991
1

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 30 IN STRESS PERIOD 11

-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                    ------------------                     ------------------------

                          IN:                                       IN:
                          ---                                       ---
                            STORAGE =    1249.1                       STORAGE =   0.34841
                      CONSTANT HEAD =   0.00000                 CONSTANT HEAD =   0.00000
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =    7734.7                      RECHARGE =    9.8320
                                 ET =   0.00000                            ET =   0.00000
0                          TOTAL IN =    8983.7                      TOTAL IN =    10.180
0                        OUT:                                      OUT:
                         ----                                      ----
                            STORAGE =    1965.7                       STORAGE =    8.5917
                      CONSTANT HEAD =    528.89                 CONSTANT HEAD =    1.6031
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =   0.00000                      RECHARGE =   0.00000
                                 ET =    6487.5                            ET =   0.00000
0                         TOTAL OUT =    8982.1                     TOTAL OUT =    10.195
0                          IN - OUT =    1.6152                      IN - OUT =  -0.14406E-01
0               PERCENT DISCREPANCY =      0.02           PERCENT DISCREPANCY =     -0.14


0


          TIME SUMMARY AT END OF TIME STEP 30 IN STRESS PERIOD 11
                               SECONDS        MINUTES         HOURS          DAYS           YEARS

---------------------------------------------------------------------------
      TIME STEP LENGTH         86400.0        1440.00        24.0000        1.00000
0.273785E-02
    STRESS PERIOD TIME        0.259200E+07    43200.0        720.000        30.0000
0.821355E-01
 TOTAL SIMULATION TIME        0.288792E+08    481320.        8022.00        334.250
0.915127
1

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 31 IN STRESS PERIOD 12

-----------------------------------------------------------------------------
0                   CUMULATIVE VOLUMES      L**3           RATES FOR THIS TIME STEP      L**3/T
                    ------------------                     ------------------------

                          IN:                                       IN:
                          ---                                       ---
                            STORAGE =    1296.3                       STORAGE =    1.4526
                      CONSTANT HEAD =   0.00000                 CONSTANT HEAD =   0.00000
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =    7734.7                      RECHARGE =   0.00000
                                 ET =   0.00000                            ET =   0.00000
0                          TOTAL IN =    9031.0                      TOTAL IN =    1.4526
0                        OUT:                                      OUT:
                         ----                                      ----
                            STORAGE =    1968.3                       STORAGE =   0.80195E-01
                      CONSTANT HEAD =    573.65                 CONSTANT HEAD =    1.3709
                              WELLS =   0.00000                         WELLS =   0.00000
                             DRAINS =   0.00000                        DRAINS =   0.00000
                           RECHARGE =   0.00000                      RECHARGE =   0.00000
                                 ET =    6487.5                            ET =   0.00000
0                         TOTAL OUT =    9029.5                     TOTAL OUT =    1.4511
```

```
0                          IN - OUT =     1.5313                          IN - OUT =   0.14504E-02
0               PERCENT DISCREPANCY =       0.02           PERCENT DISCREPANCY =       0.10


0


          TIME SUMMARY AT END OF TIME STEP 31 IN STRESS PERIOD 12
                               SECONDS        MINUTES         HOURS           DAYS           YEARS

---------------------------------------------------------------------------
      TIME STEP LENGTH         86400.0        1440.00        24.0000        1.00000
0.273785E-02
    STRESS PERIOD TIME        0.267840E+07    44640.0        744.000        31.0000
0.848734E-01
 TOTAL SIMULATION TIME        0.315576E+08    525960.        8766.00        365.250
1.00000
1
```

Table F-19 Flow Budget Analysis for the Steady-state Model at Cross-section 2 (Zone 1 is relatively high hydraulic conductivity material, Zone 2 is relatively low hydraulic conductivity material)

```
                                                       FLOW BUDGETS FOR TIME STEP    1  STRESS PERIOD   1
                                                       ==================================================


 Flow Budgets for Zones Defined in Layer  1
 ..........................................

      Zone #001 of Layer #001
      -----------------------
          IN from STORAGE:      0.0000000      OUT to STORAGE:      0.0000000       NET:
0.0000000
          IN from CONS. HEAD:   0.0000000      OUT to CONS. HEAD:   0.0000000       NET:
0.0000000
          IN from WELLS:        0.0000000      OUT to WELLS:        0.0000000       NET:
0.0000000
          IN from RECHARGE:      3.527120      OUT to RECHARGE:     0.0000000       NET:
3.527120
          IN from DRAINS:       0.0000000      OUT to DRAINS:       0.0000000       NET:
0.0000000
          IN from EVT:          0.0000000      OUT to EVT:          -1.801944       NET:
-1.801944
          IN from RIVERS:       0.0000000      OUT to RIVERS:       0.0000000       NET:
0.0000000
          IN from STREAM:       0.0000000      OUT to STREAMS:      0.0000000       NET:
0.0000000
          IN from GHB:          0.0000000      OUT to GHB:          0.0000000       NET:
0.0000000
          IN from TOP:          0.0000000      OUT to TOP:          0.0000000       NET:
0.0000000
          IN from BOTTOM:       0.2422880      OUT to BOTTOM:       -1.966035       NET:
-1.723747
          IN from ZONE #000:    0.0000000      OUT to ZONE #000:    0.0000000       NET:
0.0000000

             TOTAL INFLOW RATE=   3.769408
            TOTAL OUTFLOW RATE=  -3.767979
          ABSOLUTE DISCREPANCY=  0.1429081E-02


 Flow Budgets for Zones Defined in Layer  2
 ..........................................

      Zone #001 of Layer #002
      -----------------------
          IN from STORAGE:      0.0000000      OUT to STORAGE:      0.0000000       NET:
0.0000000
          IN from CONS. HEAD:   0.0000000      OUT to CONS. HEAD:   0.0000000       NET:
0.0000000
          IN from WELLS:        0.0000000      OUT to WELLS:        0.0000000       NET:
0.0000000
          IN from RECHARGE:     0.1209300      OUT to RECHARGE:     0.0000000       NET:
0.1209300
          IN from DRAINS:       0.0000000      OUT to DRAINS:       0.0000000       NET:
0.0000000
          IN from EVT:          0.0000000      OUT to EVT:          0.0000000       NET:
0.0000000
          IN from RIVERS:       0.0000000      OUT to RIVERS:       0.0000000       NET:
0.0000000
          IN from STREAM:       0.0000000      OUT to STREAMS:      0.0000000       NET:
0.0000000
          IN from GHB:          0.0000000      OUT to GHB:          0.0000000       NET:
0.0000000
          IN from TOP:           1.966035      OUT to TOP:         -0.2422880       NET:
1.723747
```

```
          IN from BOTTOM:       0.1678442      OUT to BOTTOM:       -2.012489       NET:
-1.844645
          IN from ZONE #000:    0.0000000      OUT to ZONE #000:    0.0000000       NET:
0.0000000

             TOTAL INFLOW RATE=   2.254809
            TOTAL OUTFLOW RATE=  -2.254777
          ABSOLUTE DISCREPANCY=  0.3147125E-04



 Flow Budgets for Zones Defined in Layer  3
 .........................................

      Zone #001 of Layer #003
      -----------------------
          IN from STORAGE:      0.0000000      OUT to STORAGE:      0.0000000       NET:
0.0000000
          IN from CONS. HEAD:   0.0000000      OUT to CONS. HEAD:   0.0000000       NET:
0.0000000
          IN from WELLS:        0.0000000      OUT to WELLS:        0.0000000       NET:
0.0000000
          IN from RECHARGE:     0.4031000E-01  OUT to RECHARGE:     0.0000000       NET:
0.4031000E-01
          IN from DRAINS:       0.0000000      OUT to DRAINS:       0.0000000       NET:
0.0000000
          IN from EVT:          0.0000000      OUT to EVT:         -0.1928163E-02   NET:
-0.1928163E-02
          IN from RIVERS:       0.0000000      OUT to RIVERS:       0.0000000       NET:
0.0000000
          IN from STREAM:       0.0000000      OUT to STREAMS:      0.0000000       NET:
0.0000000
          IN from GHB:          0.0000000      OUT to GHB:          0.0000000       NET:
0.0000000
          IN from TOP:           2.008982      OUT to TOP:         -0.1646703       NET:
1.844312
          IN from BOTTOM:       0.5086177E-02  OUT to BOTTOM:       -1.889566       NET:
-1.884479
          IN from ZONE #000:    0.0000000      OUT to ZONE #000:    0.0000000       NET:
0.0000000
          IN from ZONE #002:    0.2947071E-02  OUT to ZONE #002:   -0.2979299E-02   NET:
-0.3222772E-04

             TOTAL INFLOW RATE=   2.057325
            TOTAL OUTFLOW RATE=  -2.059143
          ABSOLUTE DISCREPANCY= -0.1817942E-02


      Zone #002 of Layer #003
      -----------------------
          IN from STORAGE:      0.0000000      OUT to STORAGE:      0.0000000       NET:
0.0000000
          IN from CONS. HEAD:   0.0000000      OUT to CONS. HEAD:   0.0000000       NET:
0.0000000
          IN from WELLS:        0.0000000      OUT to WELLS:        0.0000000       NET:
0.0000000
          IN from RECHARGE:     0.0000000      OUT to RECHARGE:     0.0000000       NET:
0.0000000
          IN from DRAINS:       0.0000000      OUT to DRAINS:       0.0000000       NET:
0.0000000
          IN from EVT:          0.0000000      OUT to EVT:          0.0000000       NET:
0.0000000
          IN from RIVERS:       0.0000000      OUT to RIVERS:       0.0000000       NET:
0.0000000
          IN from STREAM:       0.0000000      OUT to STREAMS:      0.0000000       NET:
0.0000000
          IN from GHB:          0.0000000      OUT to GHB:          0.0000000       NET:
0.0000000
          IN from TOP:          0.3506876E-02  OUT to TOP:         -0.3173952E-02   NET:
0.3329248E-03
          IN from BOTTOM:       0.1026100E-02  OUT to BOTTOM:      -0.1440488E-02   NET:
-0.4143873E-03
          IN from ZONE #000:    0.0000000      OUT to ZONE #000:    0.0000000       NET:
0.0000000
```

```
          IN from ZONE #001:    0.2979299E-02  OUT to ZONE #001:   -0.2947071E-02   NET:
0.3222772E-04

             TOTAL INFLOW RATE=  0.7512275E-02
            TOTAL OUTFLOW RATE= -0.7561510E-02
          ABSOLUTE DISCREPANCY= -0.4923530E-04


 Flow Budgets for Zones Defined in Layer  4
 ..........................................

      Zone #001 of Layer #004
      -----------------------
          IN from STORAGE:      0.0000000      OUT to STORAGE:      0.0000000       NET:
0.0000000
          IN from CONS. HEAD:   0.0000000      OUT to CONS. HEAD:   -1.800988       NET:
-1.800988
          IN from WELLS:        0.0000000      OUT to WELLS:        0.0000000       NET:
0.0000000
          IN from RECHARGE:     0.1813950      OUT to RECHARGE:     0.0000000       NET:
0.1813950
          IN from DRAINS:       0.0000000      OUT to DRAINS:       0.0000000       NET:
0.0000000
          IN from EVT:          0.0000000      OUT to EVT:         -0.2654929       NET:
-0.2654929
          IN from RIVERS:       0.0000000      OUT to RIVERS:       0.0000000       NET:
0.0000000
          IN from STREAM:       0.0000000      OUT to STREAMS:      0.0000000       NET:
0.0000000
          IN from GHB:          0.0000000      OUT to GHB:          0.0000000       NET:
0.0000000
          IN from TOP:           1.834865      OUT to TOP:          0.0000000       NET:
1.834865
          IN from BOTTOM:        1.128770      OUT to BOTTOM:       -1.093264       NET:
0.3550601E-01
          IN from ZONE #000:    0.0000000      OUT to ZONE #000:    0.0000000       NET:
0.0000000
          IN from ZONE #002:    0.1466810E-01  OUT to ZONE #002:    0.0000000       NET:
0.1466810E-01

             TOTAL INFLOW RATE=   3.159699
            TOTAL OUTFLOW RATE=  -3.159745
          ABSOLUTE DISCREPANCY= -0.4673004E-04


      Zone #002 of Layer #004
      -----------------------
          IN from STORAGE:      0.0000000      OUT to STORAGE:      0.0000000       NET:
0.0000000
          IN from CONS. HEAD:   0.0000000      OUT to CONS. HEAD:   0.0000000       NET:
0.0000000
          IN from WELLS:        0.0000000      OUT to WELLS:        0.0000000       NET:
0.0000000
          IN from RECHARGE:     0.0000000      OUT to RECHARGE:     0.0000000       NET:
0.0000000
          IN from DRAINS:       0.0000000      OUT to DRAINS:       0.0000000       NET:
0.0000000
          IN from EVT:          0.0000000      OUT to EVT:          0.0000000       NET:
0.0000000
          IN from RIVERS:       0.0000000      OUT to RIVERS:       0.0000000       NET:
0.0000000
          IN from STREAM:       0.0000000      OUT to STREAMS:      0.0000000       NET:
0.0000000
          IN from GHB:          0.0000000      OUT to GHB:          0.0000000       NET:
0.0000000
          IN from TOP:          0.5614091E-01  OUT to TOP:         -0.6112277E-02   NET:
0.5002863E-01
          IN from BOTTOM:       0.4751914E-02  OUT to BOTTOM:      -0.4013435E-01   NET:
-0.3538244E-01
          IN from ZONE #000:    0.0000000      OUT to ZONE #000:    0.0000000       NET:
0.0000000
          IN from ZONE #001:    0.0000000      OUT to ZONE #001:   -0.1466810E-01   NET:
-0.1466810E-01
```

```
            TOTAL INFLOW RATE=  0.6089282E-01
           TOTAL OUTFLOW RATE= -0.6091473E-01
         ABSOLUTE DISCREPANCY= -0.2190843E-04
```

Flow Budgets for Zones Defined in Layer 5

```
     Zone #001 of Layer #005
     -----------------------
         IN from STORAGE:      0.0000000      OUT to STORAGE:      0.0000000       NET:
0.0000000
         IN from CONS. HEAD:   0.0000000      OUT to CONS. HEAD:   0.0000000       NET:
0.0000000
         IN from WELLS:        0.0000000      OUT to WELLS:        0.0000000       NET:
0.0000000
         IN from RECHARGE:     0.0000000      OUT to RECHARGE:     0.0000000       NET:
0.0000000
         IN from DRAINS:       0.0000000      OUT to DRAINS:       0.0000000       NET:
0.0000000
         IN from EVT:          0.0000000      OUT to EVT:          0.0000000       NET:
0.0000000
         IN from RIVERS:       0.0000000      OUT to RIVERS:       0.0000000       NET:
0.0000000
         IN from STREAM:       0.0000000      OUT to STREAMS:      0.0000000       NET:
0.0000000
         IN from GHB:          0.0000000      OUT to GHB:          0.0000000       NET:
0.0000000
         IN from TOP:           1.052605      OUT to TOP:          -1.125806       NET:
-0.7320070E-01
         IN from BOTTOM:       0.5768020E-01  OUT to BOTTOM:      -0.7501535E-02   NET:
0.5017867E-01
         IN from ZONE #000:    0.0000000      OUT to ZONE #000:    0.0000000       NET:
0.0000000
         IN from ZONE #002:    0.2289444E-01  OUT to ZONE #002:    0.0000000       NET:
0.2289444E-01

            TOTAL INFLOW RATE=   1.133180
           TOTAL OUTFLOW RATE=  -1.133308
         ABSOLUTE DISCREPANCY= -0.1275539E-03


     Zone #002 of Layer #005
     -----------------------
         IN from STORAGE:      0.0000000      OUT to STORAGE:      0.0000000       NET:
0.0000000
         IN from CONS. HEAD:   0.0000000      OUT to CONS. HEAD:   0.0000000       NET:
0.0000000
         IN from WELLS:        0.0000000      OUT to WELLS:        0.0000000       NET:
0.0000000
         IN from RECHARGE:     0.0000000      OUT to RECHARGE:     0.0000000       NET:
0.0000000
         IN from DRAINS:       0.0000000      OUT to DRAINS:       0.0000000       NET:
0.0000000
         IN from EVT:          0.0000000      OUT to EVT:          0.0000000       NET:
0.0000000
         IN from RIVERS:       0.0000000      OUT to RIVERS:       0.0000000       NET:
0.0000000
         IN from STREAM:       0.0000000      OUT to STREAMS:      0.0000000       NET:
0.0000000
         IN from GHB:          0.0000000      OUT to GHB:          0.0000000       NET:
0.0000000
         IN from TOP:          0.8079354E-01  OUT to TOP:         -0.7716298E-02   NET:
0.7307725E-01
         IN from BOTTOM:       0.6068172E-02  OUT to BOTTOM:      -0.5624930E-01   NET:
-0.5018113E-01
         IN from ZONE #000:    0.0000000      OUT to ZONE #000:    0.0000000       NET:
0.0000000
         IN from ZONE #001:    0.0000000      OUT to ZONE #001:   -0.2289444E-01   NET:
-0.2289444E-01

            TOTAL INFLOW RATE=  0.8686171E-01
           TOTAL OUTFLOW RATE= -0.8686003E-01
```

```
          ABSOLUTE DISCREPANCY=  0.1683831E-05


 Flow Budgets for Zones Defined in Layer  6
 .........................................

      Zone #001 of Layer #006
      -----------------------
          IN from STORAGE:      0.0000000      OUT to STORAGE:      0.0000000       NET:
0.0000000
          IN from CONS. HEAD:   0.0000000      OUT to CONS. HEAD:   0.0000000       NET:
0.0000000
          IN from WELLS:        0.0000000      OUT to WELLS:        0.0000000       NET:
0.0000000
          IN from RECHARGE:     0.0000000      OUT to RECHARGE:     0.0000000       NET:
0.0000000
          IN from DRAINS:       0.0000000      OUT to DRAINS:       0.0000000       NET:
0.0000000
          IN from EVT:          0.0000000      OUT to EVT:          0.0000000       NET:
0.0000000
          IN from RIVERS:       0.0000000      OUT to RIVERS:       0.0000000       NET:
0.0000000
          IN from STREAM:       0.0000000      OUT to STREAMS:      0.0000000       NET:
0.0000000
          IN from GHB:          0.0000000      OUT to GHB:          0.0000000       NET:
0.0000000
          IN from TOP:          0.0000000      OUT to TOP:          0.0000000       NET:
0.0000000
          IN from BOTTOM:       0.0000000      OUT to BOTTOM:       0.0000000       NET:
0.0000000
          IN from ZONE #000:    0.0000000      OUT to ZONE #000:    0.0000000       NET:
0.0000000
          IN from ZONE #002:    0.0000000      OUT to ZONE #002:    0.0000000       NET:
0.0000000

             TOTAL INFLOW RATE=  0.0000000
            TOTAL OUTFLOW RATE=  0.0000000
          ABSOLUTE DISCREPANCY=  0.0000000


      Zone #002 of Layer #006
      -----------------------
          IN from STORAGE:      0.0000000      OUT to STORAGE:      0.0000000       NET:
0.0000000
          IN from CONS. HEAD:   0.0000000      OUT to CONS. HEAD:   0.0000000       NET:
0.0000000
          IN from WELLS:        0.0000000      OUT to WELLS:        0.0000000       NET:
0.0000000
          IN from RECHARGE:     0.0000000      OUT to RECHARGE:     0.0000000       NET:
0.0000000
          IN from DRAINS:       0.0000000      OUT to DRAINS:       0.0000000       NET:
0.0000000
          IN from EVT:          0.0000000      OUT to EVT:          0.0000000       NET:
0.0000000
          IN from RIVERS:       0.0000000      OUT to RIVERS:       0.0000000       NET:
0.0000000
          IN from STREAM:       0.0000000      OUT to STREAMS:      0.0000000       NET:
0.0000000
          IN from GHB:          0.0000000      OUT to GHB:          0.0000000       NET:
0.0000000
          IN from TOP:          0.6375082E-01  OUT to TOP:         -0.6374837E-01   NET:
0.2451241E-05
          IN from BOTTOM:       0.4677443E-01  OUT to BOTTOM:      -0.4677149E-01   NET:
0.2946705E-05
          IN from ZONE #000:    0.0000000      OUT to ZONE #000:    0.0000000       NET:
0.0000000
          IN from ZONE #001:    0.0000000      OUT to ZONE #001:    0.0000000       NET:
0.0000000

             TOTAL INFLOW RATE=  0.1105253
            TOTAL OUTFLOW RATE= -0.1105199
          ABSOLUTE DISCREPANCY=  0.5394220E-05
```

Flow Budgets for Zones Defined in Layer 7
....

Zone #001 of Layer #007

```
          IN from STORAGE:      0.0000000      OUT to STORAGE:      0.0000000       NET:
0.0000000
          IN from CONS. HEAD:   0.0000000      OUT to CONS. HEAD:   0.0000000       NET:
0.0000000
          IN from WELLS:        0.0000000      OUT to WELLS:        0.0000000       NET:
0.0000000
          IN from RECHARGE:     0.0000000      OUT to RECHARGE:     0.0000000       NET:
0.0000000
          IN from DRAINS:       0.0000000      OUT to DRAINS:       0.0000000       NET:
0.0000000
          IN from EVT:          0.0000000      OUT to EVT:          0.0000000       NET:
0.0000000
          IN from RIVERS:       0.0000000      OUT to RIVERS:       0.0000000       NET:
0.0000000
          IN from STREAM:       0.0000000      OUT to STREAMS:      0.0000000       NET:
0.0000000
          IN from GHB:          0.0000000      OUT to GHB:          0.0000000       NET:
0.0000000
          IN from TOP:          0.0000000      OUT to TOP:          0.0000000       NET:
0.0000000
          IN from BOTTOM:       0.0000000      OUT to BOTTOM:       0.0000000       NET:
0.0000000
          IN from ZONE #000:    0.0000000      OUT to ZONE #000:    0.0000000       NET:
0.0000000
          IN from ZONE #002:    0.0000000      OUT to ZONE #002:    0.0000000       NET:
0.0000000

             TOTAL INFLOW RATE=  0.0000000
            TOTAL OUTFLOW RATE=  0.0000000
          ABSOLUTE DISCREPANCY=  0.0000000
```

Zone #002 of Layer #007

```
          IN from STORAGE:      0.0000000      OUT to STORAGE:      0.0000000       NET:
0.0000000
          IN from CONS. HEAD:   0.0000000      OUT to CONS. HEAD:   0.0000000       NET:
0.0000000
          IN from WELLS:        0.0000000      OUT to WELLS:        0.0000000       NET:
0.0000000
          IN from RECHARGE:     0.0000000      OUT to RECHARGE:     0.0000000       NET:
0.0000000
          IN from DRAINS:       0.0000000      OUT to DRAINS:       0.0000000       NET:
0.0000000
          IN from EVT:          0.0000000      OUT to EVT:          0.0000000       NET:
0.0000000
          IN from RIVERS:       0.0000000      OUT to RIVERS:       0.0000000       NET:
0.0000000
          IN from STREAM:       0.0000000      OUT to STREAMS:      0.0000000       NET:
0.0000000
          IN from GHB:          0.0000000      OUT to GHB:          0.0000000       NET:
0.0000000
          IN from TOP:          0.4677149E-01  OUT to TOP:         -0.4677443E-01   NET:
-0.2946705E-05
          IN from BOTTOM:       0.2172546E-01  OUT to BOTTOM:      -0.2172440E-01   NET:
0.1059845E-05
          IN from ZONE #000:    0.0000000      OUT to ZONE #000:    0.0000000       NET:
0.0000000
          IN from ZONE #001:    0.0000000      OUT to ZONE #001:    0.0000000       NET:
0.0000000

             TOTAL INFLOW RATE=  0.6849695E-01
            TOTAL OUTFLOW RATE= -0.6849883E-01
          ABSOLUTE DISCREPANCY= -0.1884997E-05
```

Flow Budgets for Zones Defined in Layer 8

```
 ..........................................

      Zone #001 of Layer #008
      -----------------------
          IN from STORAGE:      0.0000000      OUT to STORAGE:      0.0000000       NET:
0.0000000
          IN from CONS. HEAD:   0.0000000      OUT to CONS. HEAD:   0.0000000       NET:
0.0000000
          IN from WELLS:        0.0000000      OUT to WELLS:        0.0000000       NET:
0.0000000
          IN from RECHARGE:     0.0000000      OUT to RECHARGE:     0.0000000       NET:
0.0000000
          IN from DRAINS:       0.0000000      OUT to DRAINS:       0.0000000       NET:
0.0000000
          IN from EVT:          0.0000000      OUT to EVT:          0.0000000       NET:
0.0000000
          IN from RIVERS:       0.0000000      OUT to RIVERS:       0.0000000       NET:
0.0000000
          IN from STREAM:       0.0000000      OUT to STREAMS:      0.0000000       NET:
0.0000000
          IN from GHB:          0.0000000      OUT to GHB:          0.0000000       NET:
0.0000000
          IN from TOP:          0.0000000      OUT to TOP:          0.0000000       NET:
0.0000000
          IN from BOTTOM:       0.0000000      OUT to BOTTOM:       0.0000000       NET:
0.0000000
          IN from ZONE #000:    0.0000000      OUT to ZONE #000:    0.0000000       NET:
0.0000000
          IN from ZONE #002:    0.0000000      OUT to ZONE #002:    0.0000000       NET:
0.0000000

             TOTAL INFLOW RATE=  0.0000000
            TOTAL OUTFLOW RATE=  0.0000000
          ABSOLUTE DISCREPANCY=  0.0000000


      Zone #002 of Layer #008
      -----------------------
          IN from STORAGE:      0.0000000      OUT to STORAGE:      0.0000000       NET:
0.0000000
          IN from CONS. HEAD:   0.0000000      OUT to CONS. HEAD:   0.0000000       NET:
0.0000000
          IN from WELLS:        0.0000000      OUT to WELLS:        0.0000000       NET:
0.0000000
          IN from RECHARGE:     0.0000000      OUT to RECHARGE:     0.0000000       NET:
0.0000000
          IN from DRAINS:       0.0000000      OUT to DRAINS:       0.0000000       NET:
0.0000000
          IN from EVT:          0.0000000      OUT to EVT:          0.0000000       NET:
0.0000000
          IN from RIVERS:       0.0000000      OUT to RIVERS:       0.0000000       NET:
0.0000000
          IN from STREAM:       0.0000000      OUT to STREAMS:      0.0000000       NET:
0.0000000
          IN from GHB:          0.0000000      OUT to GHB:          0.0000000       NET:
0.0000000
          IN from TOP:          0.2172440E-01  OUT to TOP:         -0.2172546E-01   NET:
-0.1059845E-05
          IN from BOTTOM:       0.0000000      OUT to BOTTOM:       0.0000000       NET:
0.0000000
          IN from ZONE #000:    0.0000000      OUT to ZONE #000:    0.0000000       NET:
0.0000000
          IN from ZONE #001:    0.0000000      OUT to ZONE #001:    0.0000000       NET:
0.0000000

             TOTAL INFLOW RATE=  0.2172440E-01
            TOTAL OUTFLOW RATE= -0.2172546E-01
          ABSOLUTE DISCREPANCY= -0.1059845E-05
```

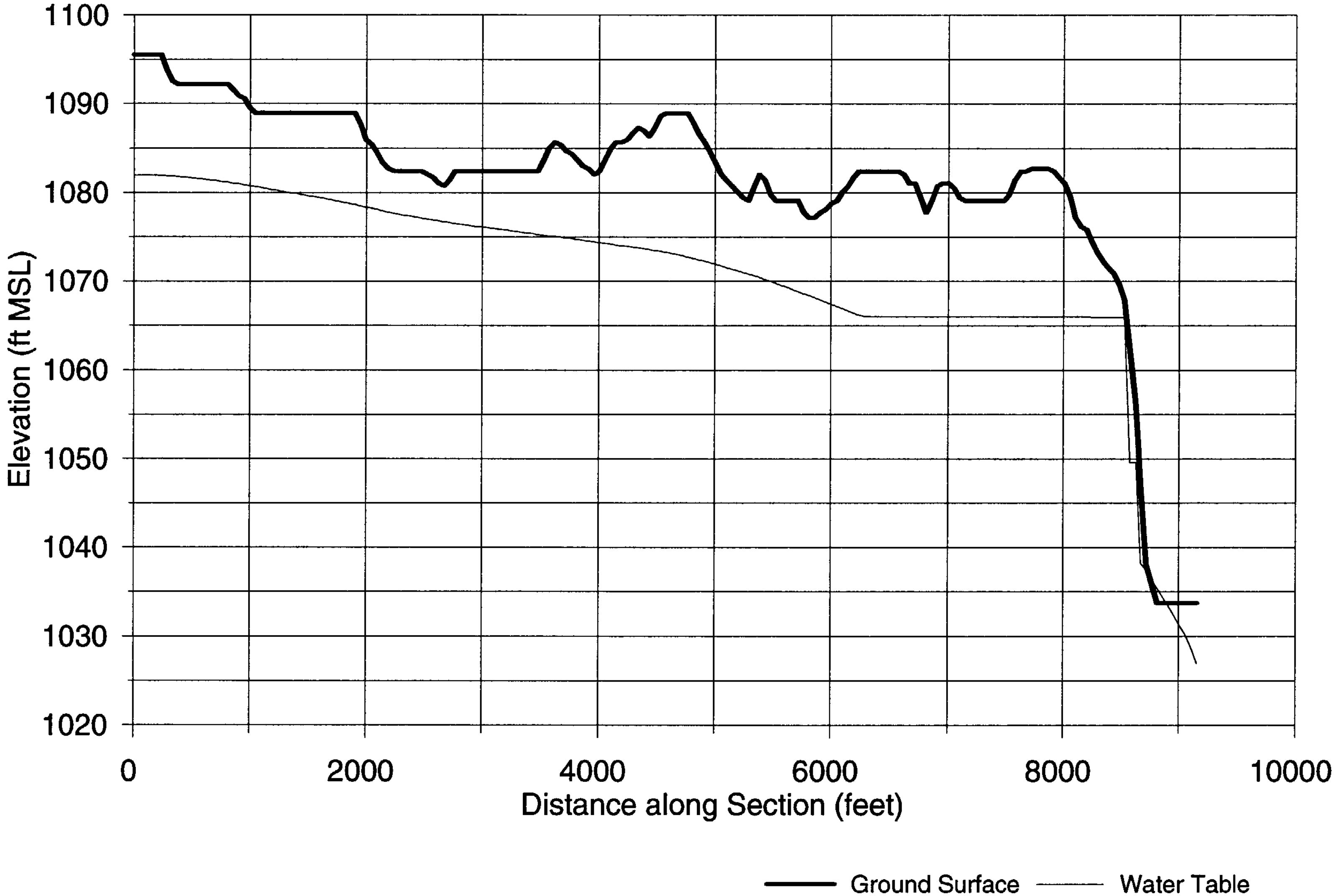

Figure F-1
Profile of Cross-section Model 2 Showing Ground Surface and
Simulated Water Table Elevation for Typical Summer Conditions

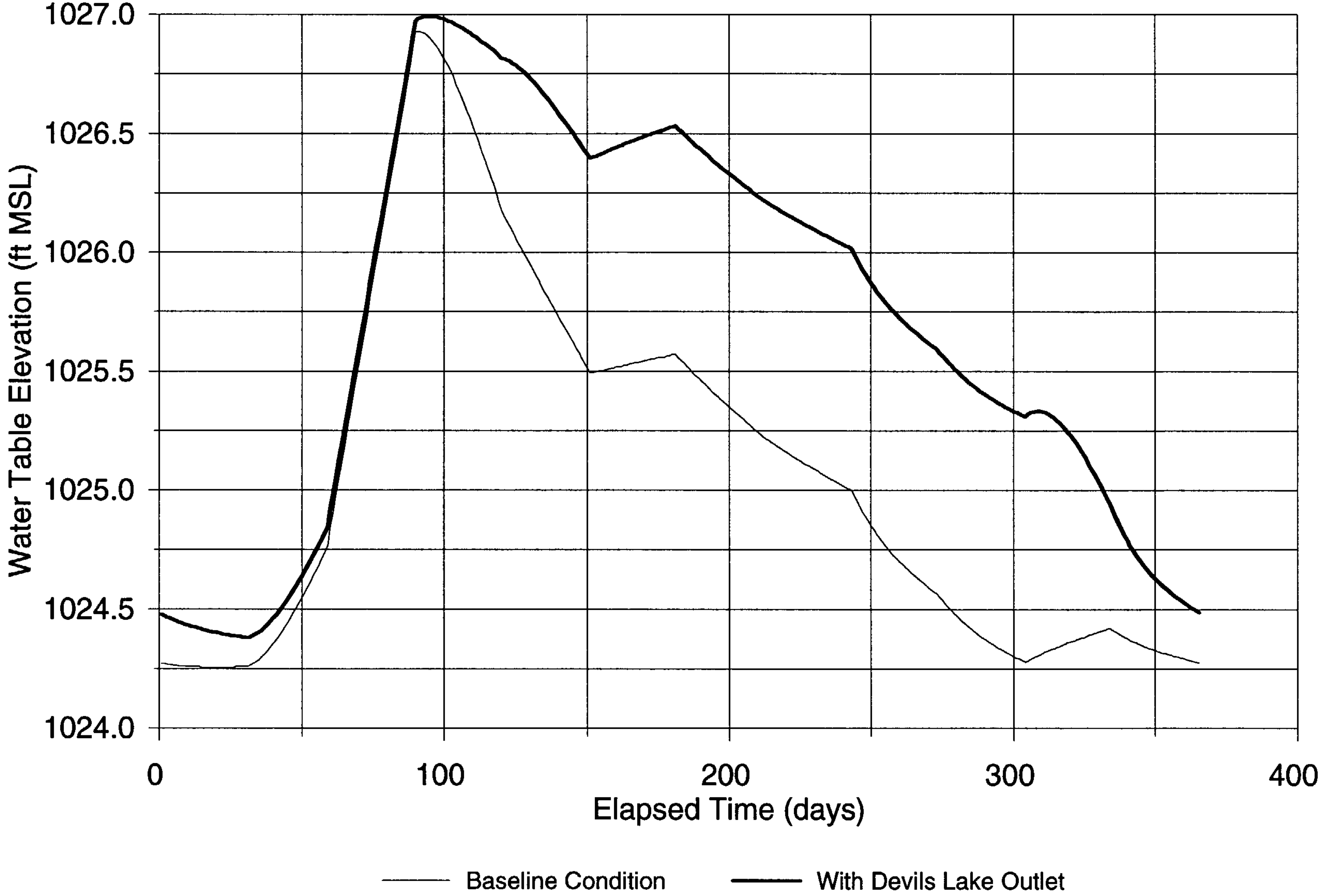

Figure F-2
Simulated Water Levels 48 feet from the Sheyenne River throughout a Typical Year (Cross-section 2)

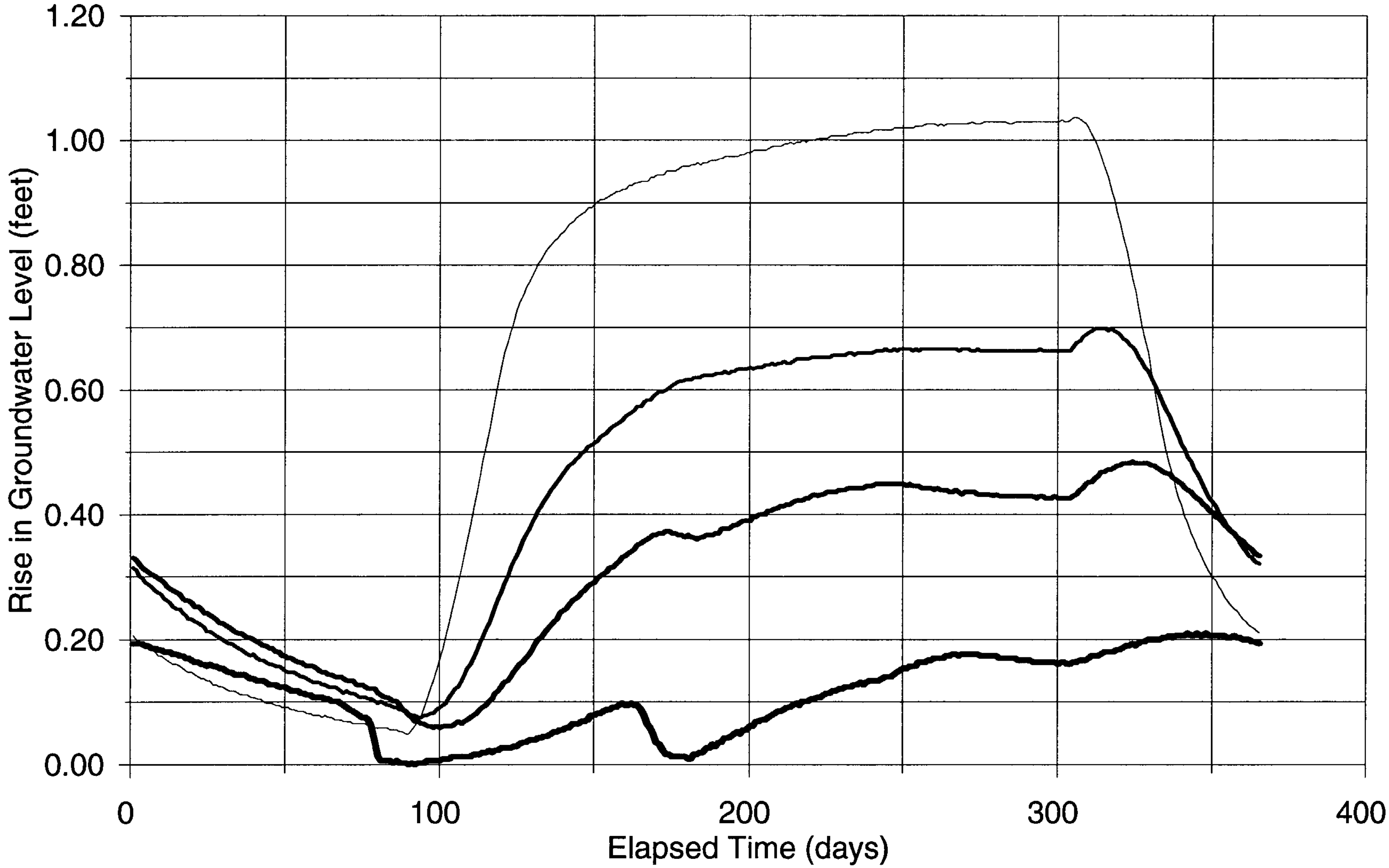

Figure F-3
Simulated Rise in Water Level due to the Devils Lake Outlet throughout a Typical Year at Various Distances from the Sheyenne River (Cross-section 2)

48 95 143 238

Distance from the river in feet

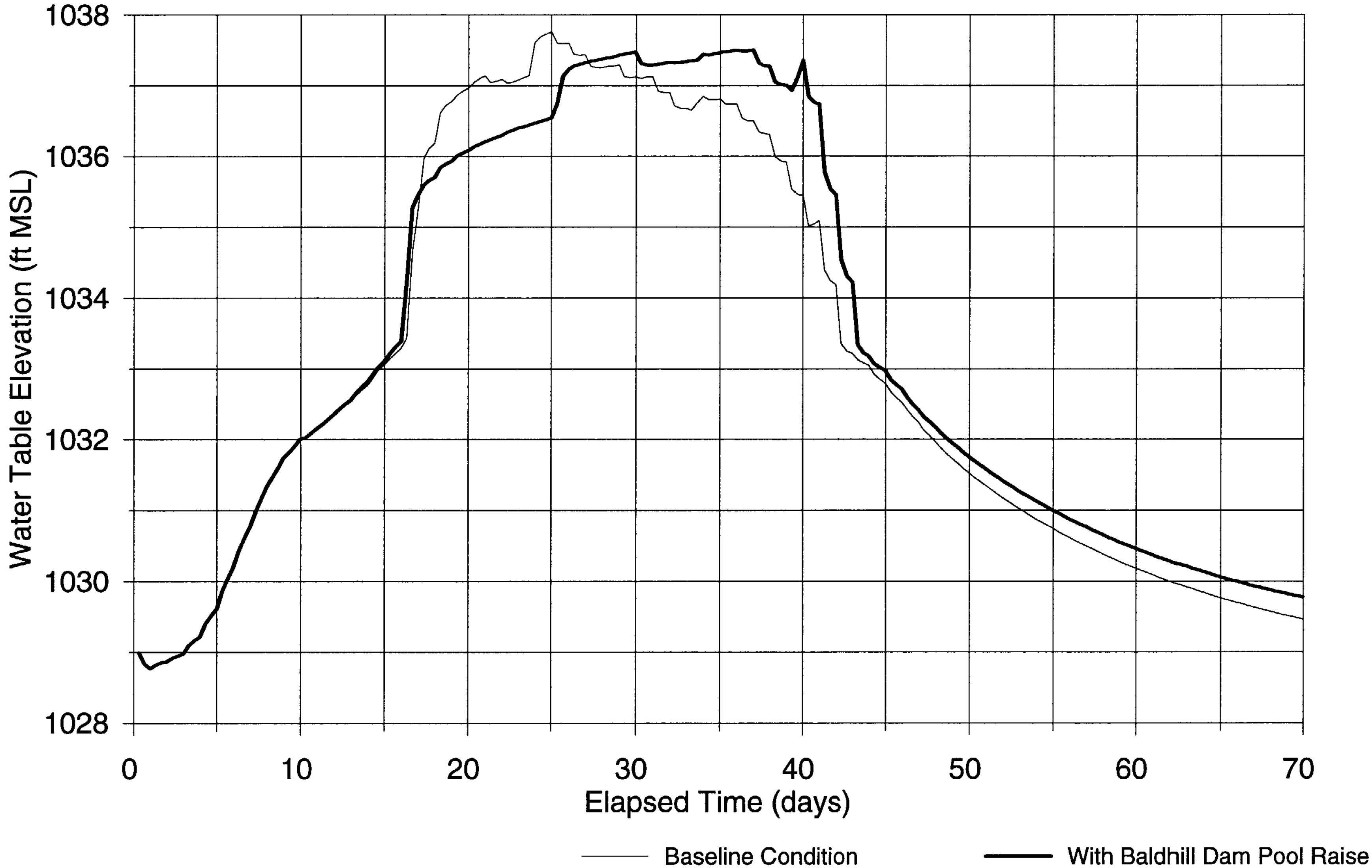

Figure F-4
Simulated Water Levels 48 feet from the Sheyenne River throughout a 100-year Flood Event (Cross-section 2)

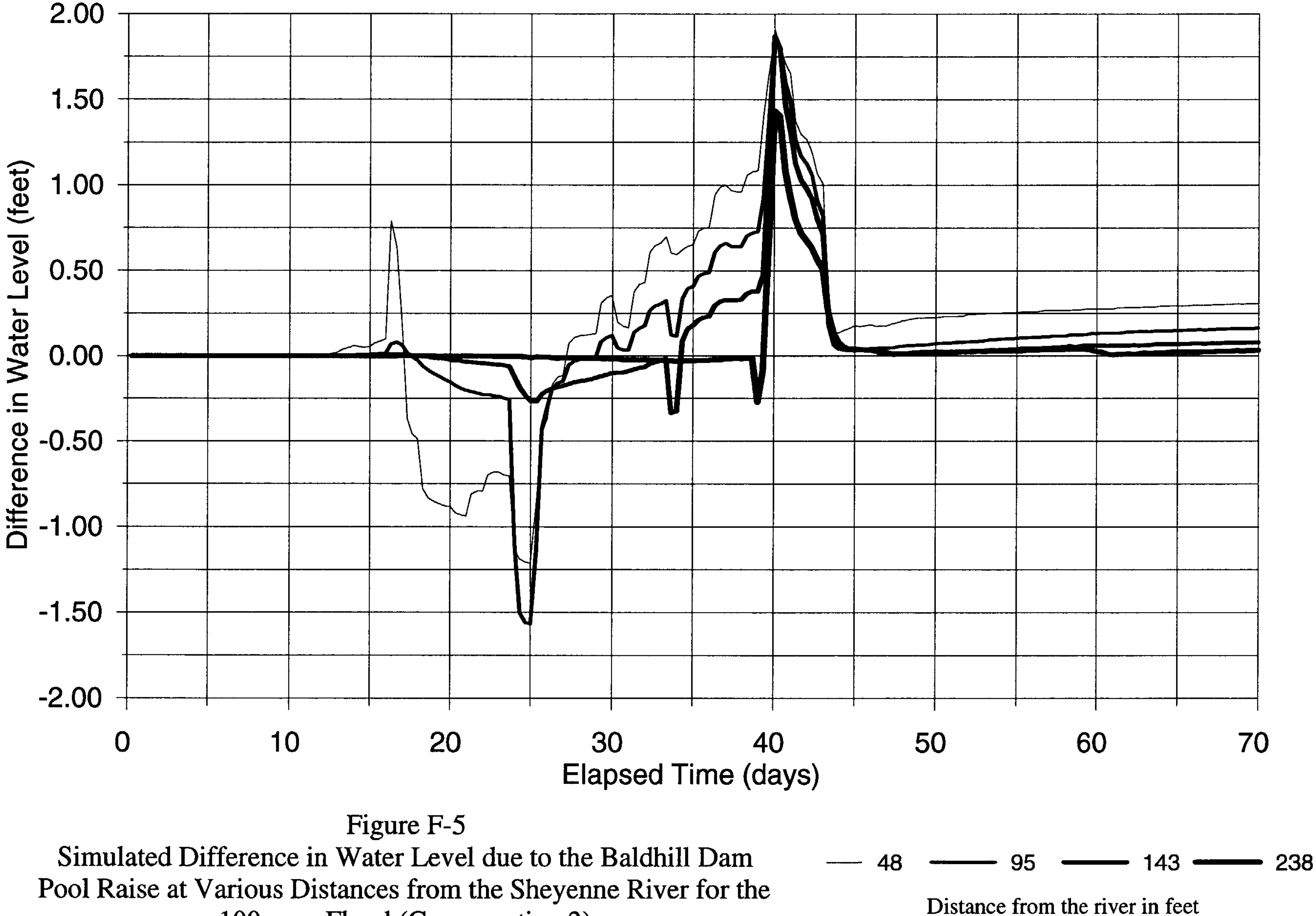

Figure F-5
Simulated Difference in Water Level due to the Baldhill Dam Pool Raise at Various Distances from the Sheyenne River for the 100-year Flood (Cross-section 2)

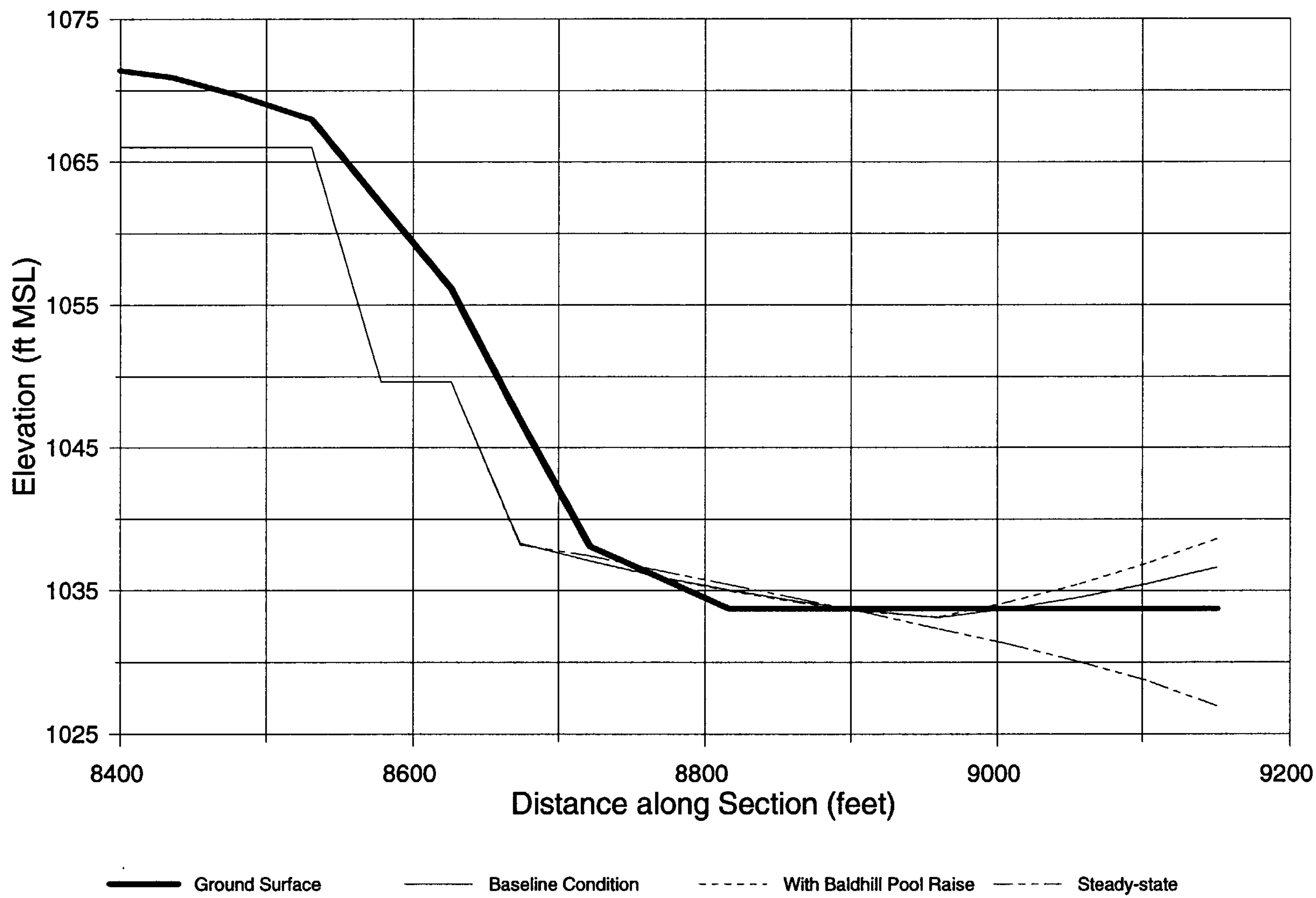

Figure F-6
Profile of Cross-section Model 2 Showing Ground Surface and
Simulated Water Table Elevation at the Maximum River Stage of a 100-year Flood

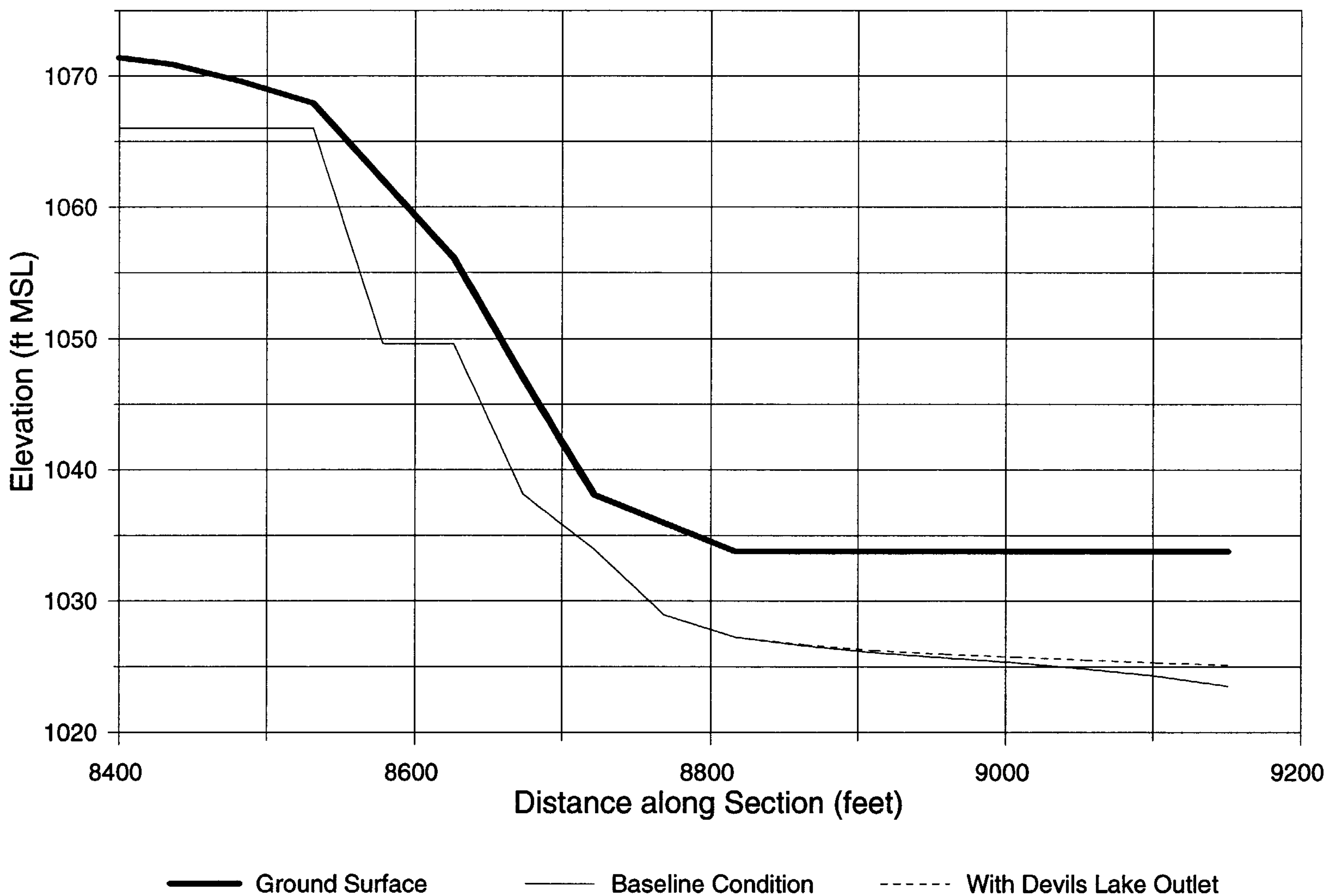

Figure F-7
Profile of Cross-section Model 2 Showing Ground Surface and Simulated Water Table Elevations at the Maximum Difference in Groundwater Elevation (November 1)

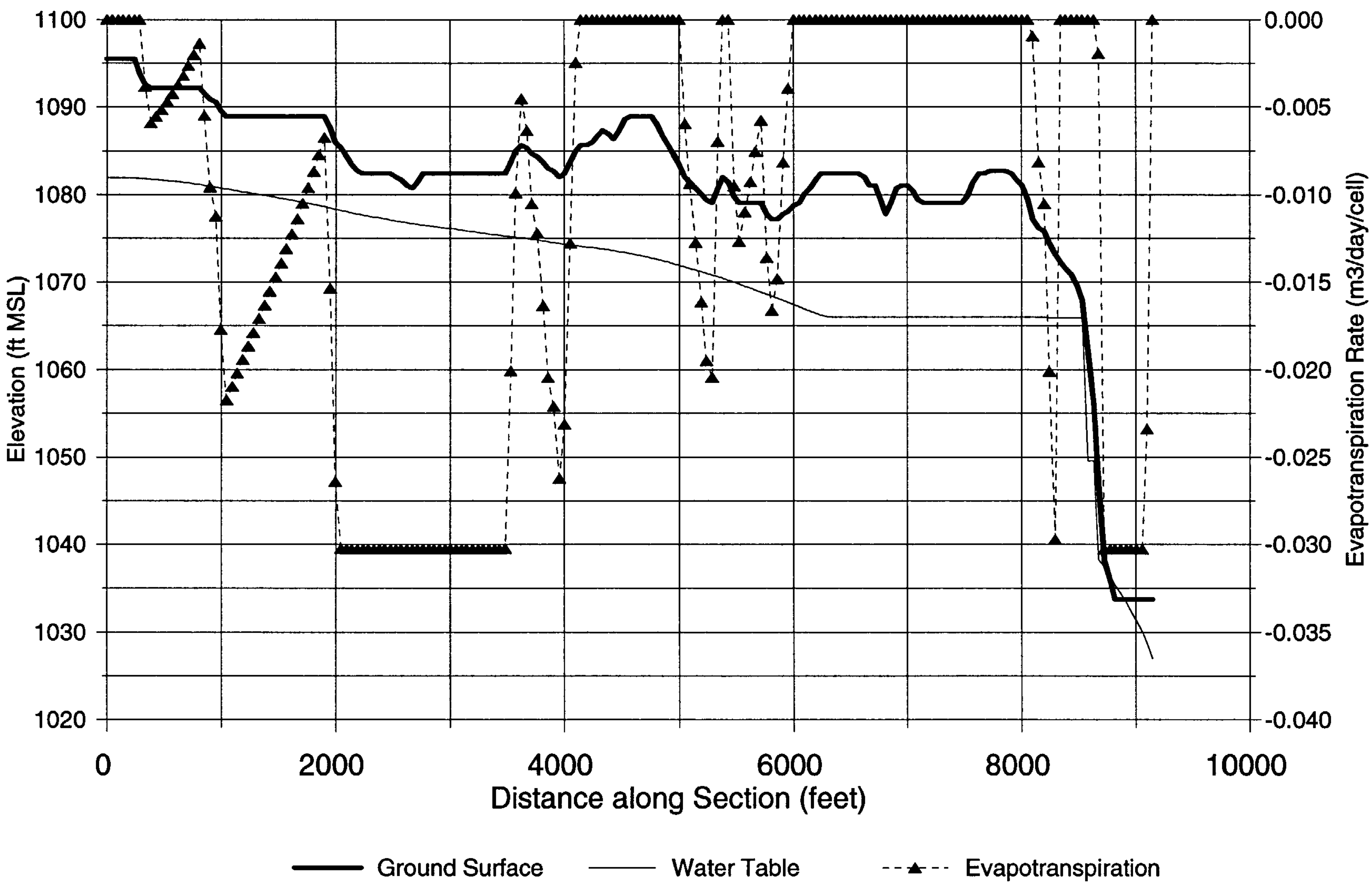

Figure F-8
Profile of Cross-section Model 2 Showing Ground Surface, Simulated Water Table Elevation for Typical Summer Conditions, and Evapotranspiration Rates

Appendix G

Memorandum Regarding Simulation of Controlled Release from Baldhill Pool as Observed at Walcott, ND

BARR

MEMORANDUM

To: Project File (34/39-004RWW)

From: Dave Dahlstrom

Subject: Simulation of Controlled Release from Baldhill Dam as Observed at Walcott, ND

Date: 4/22/99

The USGS performed monitoring of river stage and groundwater levels at two sites along the Sheyenne River during October and November of 1998 during a controlled release of water from the Baldhill Pool (Emerson, et al, 1999). The USACOE asked Barr to simulate the controlled release and compare simulated and measured results as part of the current project evaluating the effects of the Planned Operation of the Devils Lake Outlet and Baldhill Pool Raise Projects on Groundwater Levels in the Sheyenne Delta.

One site, near Kathryn, ND is located beyond the limits of the Sheyenne Delta. The other site, near Walcott, ND is located approximately three miles from the nearest cross-section constructed by Barr to evaluate the effects of the possible Devils Lake Outlet and Baldhill Pool Raise projects. The USGS installed wells north and south of the river at the following distances from the river: 25 feet, 50 feet, 75 feet, and 150 feet. The cross-sectional models prepared by Barr simulate areas south of the river (Barr, 1998). The nearest cross-sectional model to Walcott was modified from a regular mesh to an irregular mesh to allow comparison with closely-spaced wells installed by the USGS south of the Sheyenne River. The original model had a regular grid spacing of 297 feet.

River stage was measured manually nine times over the monitoring period. The river stages were used to divide the monitoring period into six MODFLOW stress periods. These river stages were inserted in the specified head package. The total simulation was for the period from November 6, 1998 to December 15,

1998. The river stage measurement on November 9 is suspect, because the observed water levels do not show a similar response at this time. Because the river was not continuously monitored, the peak river stage may have been missed and the time at which river stage recession began is not precisely known.

The measured and simulated hydrographs for the four wells are shown on Figures 1 through 4. The total amplitude of observed and simulated water level changes are summarized on Table 1.

The MODFLOW simulation predicts a steeper groundwater gradient toward the river; and underpredicts the amplitude of the response at 150 feet from the river (Figure 4), suggesting that the hydraulic conductivity used in the model may be too low. The simulated response to river stage changes overpredicts the amplitude of the response at 25 feet from the river (Figure 1); and is more rapid than observed suggesting that the river is not as well connected to the flow system as assumed or that the specific yield used in the model is too low. For instance, the simulated peak in groundwater level in the well 150 feet from the river occurred approximately 2 days before the observed peak (Figure 4). Calibration of the model to the observed response is beyond the scope of the current project.

Another possible cause for the larger difference between measured and simulated water level changes at Well 4 is that the geometry of the river in this area is more complicated than assumed by the conceptual hydrogeologic model. The cross-sectional modeling approach assumes the river is straight. In fact, the well nest near Walcott is located near a tight meander and Well 4 is located 375 feet from an upstream section of the river (see Figure 2 from Emerson, et al, 1999, attached to this memo). The response to the river stage change measured at Well 4 was likely affected by both boundaries. Construction of a three-dimensional model to more accurately simulate the boundary geometry is beyond the scope of the current project.

In general, the conclusions reached in Barr, 1998 are consistent with the observed response to the controlled release within the accuracy requirements in the Scope of Work. The effects of river stage changes appear to be limited to areas very near the river.

REFERENCES

Barr Engineering Company, 1998. Devils Lake Outlet/Baldhill Pool Raise. Independent Analysis of Effects of the Planned Operation of the Devils Lake Outlet and Baldhill Pool Raise Projects on Groundwater Levels in the Sheyenne Delta. Draft Report, September, 1998.

Emerson, D.G., J.D. Wald, and M.L. Strobel, 1999. Progress Report, February, 1999: Relation between Streamflow and Ground Water in the Sheyenne River Valley near Kathryn and Walcott, North Dakota. Preliminary Draft.

Table 1

Total Measured and Simulated Water Level Change During the Controlled Release

Distance from River to Well (ft)	Measured Water Level Change (ft)	Simulated Water Level Change (ft)
25	1.33	2.02
50	1.21	1.58
75	1.10	1.18
150	1.06	0.34

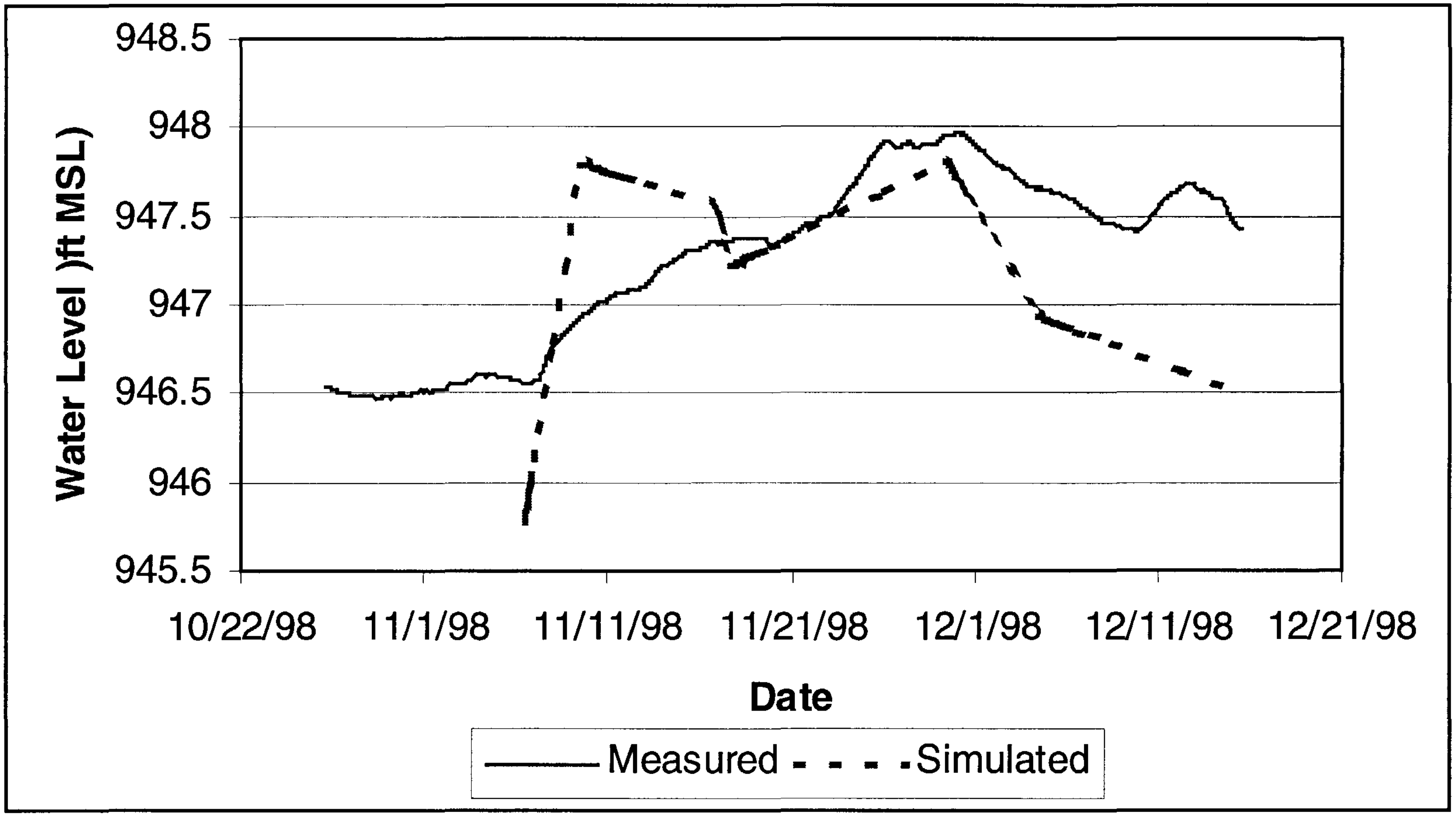

Figure 1

Predicted Water Levels in Well 1, Located 25 feet from the Sheyenne River Near Walcott, ND During the Controlled Release from the Baldhill Pool

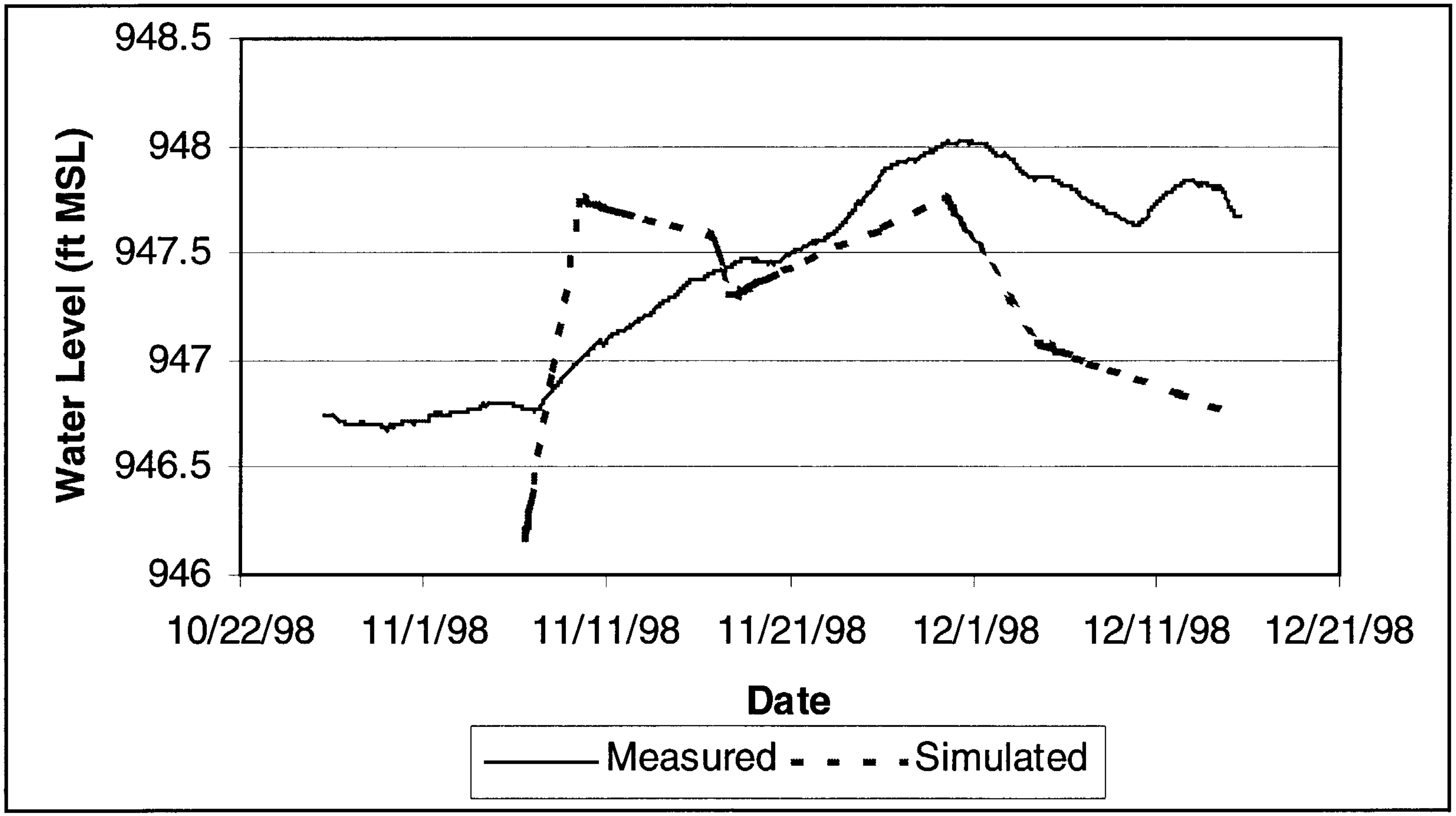

Figure 2

Predicted Water Levels in Well 1, Located 50 feet from the Sheyenne River Near Walcott, ND During the Controlled Release from the Baldhill Pool

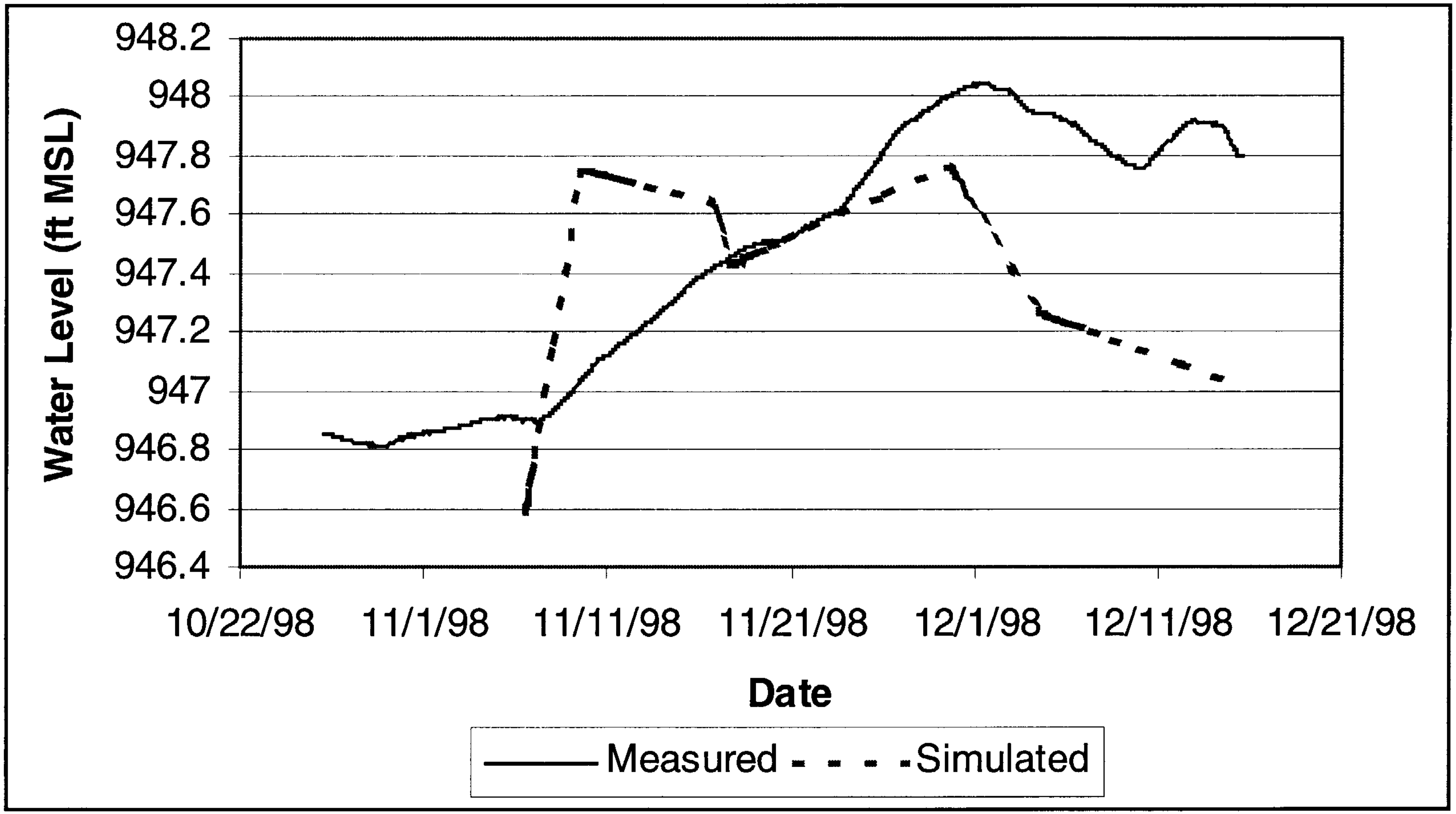

Figure 3

Predicted Water Levels in Well 1, Located 75 feet from the Sheyenne River Near Walcott, ND During the Controlled Release from the Baldhill Pool

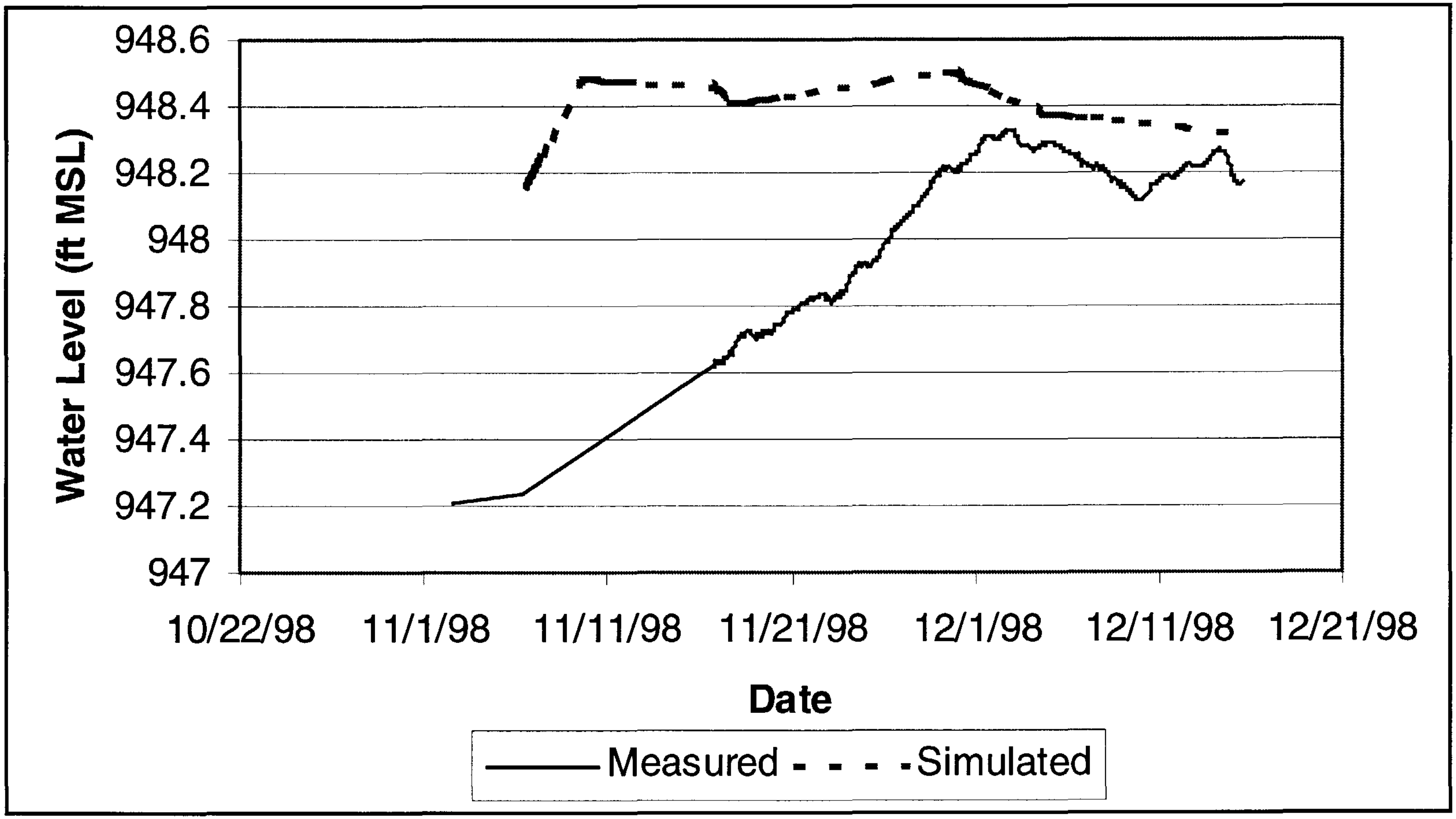

Figure 4

Predicted Water Levels in Well 1, Located 150 feet from the Sheyenne River Near Walcott, ND During the Controlled Release from the Baldhill Pool

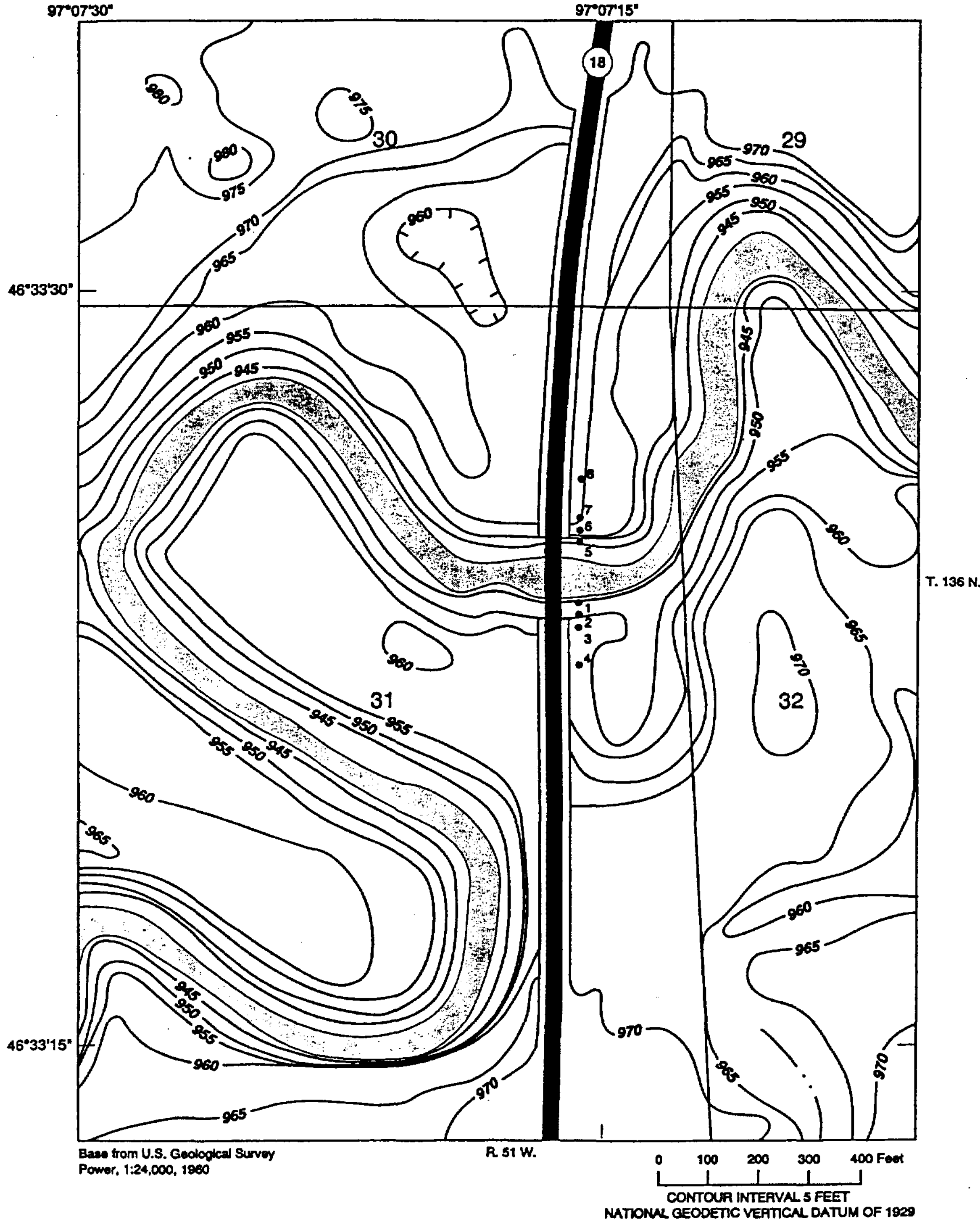

Figure 2. Location of wells 1–8 at the Sheyenne River near Walcott, N. Dak., site.

Figure 5

Location Figure from Emerson, et al, 1999